Control of Certain Ditchbank Weeds on Irrigation Systems

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Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
State Agricultural Experiment Stations
and the
Bureau of Reclamation, U.S. Department of the Interior

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By J. M. Hodgson, V. F. Bruns, F. L. Timmons, W. O. Lee, L. W. Weldon, and R. R. Yeo, *research agronomists, Crops Research Division, Agricultural Research Service*[1]

Weeds on ditchbanks are a major obstacle in irrigating arid croplands in the Western United States. They also seriously interfere with drainage of irrigation water from many of the same croplands. As reported by Timmons and Klingman (*13*),[2] they reduce the flow of water and thus cause flooding (fig. 1), seepage, breaks in ditchbanks, increased evaporation and transpiration loss, decreased water delivery to farmland, and decreased drainage of water from farmlands. They obstruct inspection and maintenance operations of the irrigation systems and cause silt deposits in the irrigation channels (*1*). According to a survey made in 1960 (*12*), weeds infested nearly 400,000 acres of ditchbanks along irrigation and drainage canals in the 17 Western States in 1957 and caused the loss of 600,000 acre-feet of water and total losses estimated at $1,767,174. Ditchbank weeds are also a potential source of invasion into croplands from seed or other viable plant structures (*1*).

Many plant species are included collectively in the term "ditchbank weeds." Bruns and Wolfe (*5*) have described control measures for 24 species of common field annuals, biennials, and perennials, that occur on ditchbanks in Washington. Any plant, whether of a wet or dry habitat, that becomes established along the ditch and interferes with waterflow or presents a hazard to adjacent farmland is termed a ditchbank weed. They include perennial noxious species, such as Canada thistle and quackgrass, woody species, such as willows and wild rose, and annuals, such as sunflower and Russian-thistle. Johnsongrass is a major ditchbank weed in many areas. Effective control treatments for Johnsongrass were developed by Arle and coworkers and reported in 1955 and 1958 (*3*, *4*). Even misplaced crop plants, such as sweetclover and forage grasses, often become troublesome on ditchbanks.

This report presents results of research conducted in five Western States, to develop methods for the control of several of the more troublesome ditchbank weeds.

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[1] The authors conducted research at the following locations: J. M. Hodgson at Meridian, Idaho, and Bozeman, Mont.; V. F. Bruns at Prosser, Wash.; F. L. Timmons and W. O. Lee at Logan, Utah, and Laramie, Wyo.; L. W. Weldon at Laramie, Wyo.; and R. R. Yeo at Huntley, Mont. The authors appreciate the assistance of R. D. Comes, research agronomist, in preparing first drafts of the research reported from Wyoming.

[2] Italic numbers in parentheses refer to Literature Cited, p. 64.

FIGURE 1.—A roadway flooded with water from a ditch clogged with weeds.

FACTORS RELATED TO THE IRRIGATION DITCHBANK VEGETATION PROBLEM

Ditchbanks provide a variable plant habitat. A major reason for this is that soil moisture varies greatly within a short distance on an irrigation ditchbank. Species that are adapted to high moisture levels and that grow with their roots in the wet soil are often found at the waterline. Within a few feet of this area, up over the top of the bank, the soil may be very dry with drought-tolerant species predominating. In certain soils, seepage may occur through the ditchbank so that the back side is quite wet instead of being dry. This is especially true where borrow pits have been made during construction of built-up ditchbanks. These borrow pits often collect field drainage water as well as ditch seepage and thus create a wet type of plant habitat. Ditchbanks that have been built up by bringing in extra soil may be very dry and may need certain adapted plants to stabilize the bank against erosion and to prevent establishment of unwanted plants.

Weeds generally have more limiting effects upon intermittently used channels or those of low waterflow capacity, because of their ability to extend themselves into a greater area of the channel.

Although rank vegetation on ditchbanks is disadvantageous, some vegetation usually is useful. In soils that are easily eroded by wind or water action or on ditchbanks being pastured, soil-binding vegetation, such as grasses, is desirable. Vegetation is also vitally needed on steeper sloping ditches, where the water flows more rapidly. Therefore, the ditchbank-vegetation control problem should be considered

from many angles so that the treatment can be suited to particular ditches.

Sometimes vegetation-control treatments are less effective on the most undersirable species; as a result, these species begin immediately to occupy the area where other less harmful plants were controlled. In certain instances this has resulted in the spread of the less desirable plant and caused a more difficult control problem (fig. 2).

FIGURE 2.—A ditchbank infested with wild rose after willows have been killed with 2,4-D.

Livestock grazing on ditchbanks has been highly recommended for vegetation control (*1*, *6*) (fig. 3). Several irrigation districts have found this to be an economical means of weed control on ditchbanks. However, grazing is not practical in some areas because of soil type or steepness of banks. Also some farmers prefer not to bother with fencing and other details of handling livestock.

Some irrigation operators have constructed lined ditches or pipelines beneath the ground surface as the best solution of bank-vegetation control as well as other ditch problems. On high-value land and under critical water-supply conditions this method of delivering water seems well justified when compared with unlined open ditches.

Mowing for ditchbank-weed control is still practiced and is effective in limiting seed production and growth of such plants as Canada thistle, wild rose, or wild mustard. This method encourages growth of perennial grasses. However, the mower often does not reach all plants on the banks. Certain boom-type bottled-gas burners are effective for plant control. The main shortcomings of this treatment are the cost and necessity for frequent retreatments. Crafts (*6*) stated that mowing followed by burning gave satisfactory seasonal control of annuals and some perennials.

With the introduction of many new chemicals for weed control, considerable research has been done to determine which are effective in controlling ditchbank vegetation and how and when to use them for

FIGURE 3.—A ditchbank pastured with livestock (right) and unpastured (left).

best results (*5, 7, 8*). Results of several experiments for control of plants found to be troublesome on ditchbanks in irrigated areas of the Western United States are given in this report.

GENERAL PROCEDURE

The investigations reported herein were conducted on various irrigation projects in Idaho, Montana, Washington, Wyoming, and Utah under general supervision of a regional coordinator, or investigations leader. Close liaison was maintained between investigators at the various locations, and there was considerable similarity in method of approach and general procedure. However, the plans of experiments varied with species of weeds, types of ditchbanks, and local situations as necessary to provide the most suitable experimental conditions in each situation. Experimental plots were laid out on ditchbanks or other locations where the particular weed species occurred naturally. The ditchbanks in the tests ranged from those along small intermittently used ditches to those along large channels in which water flowed continuously for an entire irrigation season. Chemicals were applied with small, engine-driven sprayers or compressed-air, knapsack-type sprayers. The site characteristics of each location varied accordingly as did the location.

A detailed description of site characteristics and experimental materials and methods in each experiment is included in the report of

that experiment. The reports of individual experiments are grouped by types of ditchbank weeds and by species within each type.

For the sake of brevity the common names or symbols of the herbicides are used throughout the report. Common names or symbols and chemical names of all herbicides tested in the experiments are given in the tabulation that follows.

Common and chemical names of herbicides used in investigations:

Common name	*Chemical name and constituents*
Amitrole	3 amino-1,2,4-triazole
Amitrole-T	3 amino-1,2,4-triazole (50 percent) plus ammonium thiocyanate (50 percent)
AMS	Ammonium sulfamate
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-triazine
BDM	Disodium borate (88.5 percent) and 2,4-D (7.5 percent)
BMM	Sodium borate (94 percent) and monuron (4 percent)
CBM	Sodium chlorate (25 percent) and sodium borate (73 percent)
CBMM	Sodium chlorate (40 percent), sodium metaborate (57 percent), and monuron (1 percent)
Chlorazine	2-chloro-4,6-bis(diethylamino)-s-triazine
CIPC	Isopropyl N-(3-chlorophenyl) carbamate
Dalapon	2,2-dichloropropionic acid
Diquat	1,1-ethylene-2,2-dipyridylium dibromide
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
DNBP	4,6-dinitro-*o-sec*-butylphenol
Erbon	2-(2,4-5-trichlorophenoxy) ethyl 2,2-dichloropropionate
Fenuron	3-phenyl-1,1-dimethylurea
FenuronTCA	3-phenyl-1,1-dimethylurea trichloroacetate
Fuel oil	Fuel oil
HCA	Hexachloroacetone
Herbicidal oil	Herbicidal oil containing 55 percent aromatics
MCPA	2 methyl-4 chlorophenoxyacetic acid
Prometone	2-methoxy-4,6-bis(isopropylamino)-s-triazine
MH	Maleic hydrazide
Monuron	3-(p-chloro-phenyl)-1-1-dimethylurea
MonuronTCA	3-(p-chlorophenyl)-1,1-dimethylurea trichloroacetate
PBA	Polychlorinated benzoic acid
PCP	Pentachlorophenol
Silvex	2-(2,4-5-trichlorophenoxy) propionic acid
Simazine	2-chloro-4,6-bis(ethylamino)-s-triazine
TCA	Sodium trichloroacetate
2,4-D	2,4-dichlorophenoxyacetic acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,3,6-TBA	2,3,6-trichlorobenzoic acid

EXPERIMENTAL RESULTS

PERENNIAL GRASSES AND CAREX

Reed Canarygrass

Reed canarygrass (*Phalaris arundinacea* L.) is a hardy perennial that is aggressive in wet, poorly drained, and moderately alkaline soils. This grass is sometimes grown for forage in the cool Northern States, especially in places too wet for growing more palatable species.

Reed canarygrass is undesirable on banks of irrigation and drainage systems for several reasons. The rank foliage grows 3 to 6 feet tall

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FIGURE 4.—A heavy infestation of canarygrass along an irrigation canal in Utah.

and conceals irrigation structures and bank faults. It encroaches and lodges in the ditch at the waterline and impedes the normal flow of water (fig. 4); this necessitates extra cleaning work. It is particularly troublesome on small laterals and drains, which can become completely clogged by the growth. In ditches that carry water intermittently the rhizomes gradually creep into the ditch bottoms. These rhizomes hinder waterflow and accumulate silt, which in turn promotes more rhizome development. This action progressively produces a berm that extends into the ditch. Within a short time the flow of water may be drastically reduced, and costly ditch cleaning must be undertaken. As the older plants die and roots decay loss of irrigation water may occur through seepage.

Mowing, scything, and other mechanical methods of control are expensive and only partially effective. Sometimes pasturing has been effective; however, grazing cannot be used to advantage in many situations. Experiments to control canarygrass with chemicals were conducted in Utah in 1951 to 1954 and in Montana in 1958 and 1959.

Experiments in Utah

In Utah the objective was complete eradication of all canarygrass on a strip extending from the waterline up the canal bank to a point about 5 feet beyond the edge of the canal shoulder. Soil-sterilant treatments on mature unburned vegetation were compared with similar treatments made after removal of vegetation by burning. These plots were located on banks of a medium-sized canal that carried water continuously for the irrigation season. All herbicides were applied with an

engine-driven sprayer, equipped with pressure regulator, bypass system, and single-nozzle hand boom.

Soil sterilants (1951).—The chemicals were applied November 2, 1951 and included monuron at rates of 30, 45, 60, 90, and 120 pounds per acre, sodium chlorate at 480, 720, and 960 pounds per acre, and CBM at 960, 1,440, and 1,920 pounds per acre.

In the spring of 1952, the control appeared to be better from sodium chlorate and the CBM than from monuron. However, by September, results from monuron were much better than those from the other two materials. The average percent survival of reed canarygrass in September was 68, 50, 55, 35, and 10 percent, respectively, for the different rates of monuron as compared with 90, 90, and 83 percent for chlorate and 80, 83, and 85 percent for the different rates of CBM. The latter two materials appeared to leach out of the soil rapidly, especially near the waterline. This permitted the rapid recovery of the grass late in the season. Monuron appeared to maintain its effectiveness even at the waterline, but the denuded banks tended to crack and slough into the canal (fig. 5).

Soil sterilants (1952).—In the experiment initiated in December 1952, monuron, sodium chlorate, and CBM were again compared. The rates of application were the same except for the CBM, for which the rates of application were increased to 1,120, 1,920, and 2,240 pounds per acre. One series of treatments was made in December 1952 with the old vegetation present on the plots. Another series of treatment was made in March 1953 on plots from which the vegetation had been burned. Each treatment was replicated twice in both series.

Observations made in September 1953 showed that none of the treatments made the previous December gave satisfactory grass control. Survival ranged from 33 to 60 percent with no consistent difference for chemical or rate of application. On the series of plots treated in March, results were much better, especially on those treated with monuron, where the survival of canarygrass ranged from only 1 percent at 120 pounds per acre to 18 percent at 60 pounds per acre. Spring treatments of chlorate and CBM gave better control than the fall treatments; however, 25 to 37 percent of the canarygrass survived the highest rates of these two chemicals.

Probably the poor results from the December application were due to the heavy mat of vegetation on the plots at the time of treatment. This organic matter may have absorbed much of the chemical and prevented its moving into the soil. Removal of this vegetation by burning before the March treatments probably contributed to the better results.

All plots initially treated in December 1952 were retreated in December 1953, while those initially treated in March 1953 were retreated in April 1954. A uniform application of 45 pounds of monuron, 1,400 pounds of sodium chlorate, and 1,920 pounds of the CBM was made on plots receiving these chemicals in the initial treatments. Observations made October 1, 1954, showed that the retreatments made in the fall of 1953 and spring of 1954 did not increase the percent kill of the canarygrass. Precipitation during the winter of 1953–54 and the spring of 1954 was considerably below

normal, and it is believed that the retreatments failed to increase the kill of the canarygrass because of the moisture deficiency.

Soil sterilants (1953).—In this test monuron at 60, 90, and 120 pounds per acre, fenuron at 60, 90, and 120 pounds per acre, sodium chlorate at 1,440 pounds per acre, CBM at 1,920 pounds per acre, and and CBMM at 840 pounds per acre were compared. One series of applications was made in December 1953 and a second series in March 1954. The vegetation produced in 1953 was removed by burning in December prior to the December and March treatments. All treatments were replicated three times in each series.

Observations were made October 1, 1954. Plots treated in December 1953 showed 28 percent survival of reed canarygrass for the CBMM, 38 percent for chlorate, 43 to 55 percent for the heavy rates of monuron and fenuron, 63 to 80 percent for CBM, and 80 percent for the lighter rates of monuron and fenuron. Plots treated in March 1954 showed no distinct difference for chemical or rate of application. Survival ranged from 35 to 53 percent.

The unsatisfactory results of this experiment may have been a result of insufficient precipitation to move the chemicals into the root zone of the canarygrass.

Experiments in Montana

In the experiments in Montana, several contact herbicides, growth inhibitors, and soil sterilants were tested for control of canarygrass. Plots for the treatments were established in heavy infestations on delivery and drainage ditches of the Huntley irrigation project. These ditches ranged in waterflow capacity from 5 to 25 cubic feet per second. All ditches carried water continuously from May to September each season.

Contact herbicides.—Several contact herbicides were applied to reed canarygrass during 1958 and 1959 to determine the most effective treatment for growth suppression (table 1). The herbicides were first applied in May, when the canarygrass was 18 to 24 inches tall. The plots were retreated twice each year when the earliest recovering plants were 12 to 18 inches tall. The surviving canarygrass was harvested in October each year, about 6½ weeks after the third application, to determine the effects of the treatments.

In 1959, two new treatments—a light and a heavy burn with a propane burner—were added. The light burn caused only slight wilting of the canarygrass; whereas, the heavy burn caused wilting and charred the edges and tips of leaves.

All chemical treatments significantly reduced the yield of canarygrass (table 1). When all treatments are compared for both years, herbicidal-oil treatments at 100 and 120 gallons per acre gave the most effective control of canarygrass. Yields of canarygrass were somewhat variable from the herbicidal oil and PCP combination treatments. Results for the 2 years indicate that the addition of PCP did not enhance the effectiveness of the herbicidal oil.

Herbicidal oil and growth inhibitors.—To study the possibility of enhancing the effectiveness of herbicidal oil in controlling reed canarygrass, several growth-inhibitor chemicals were applied as

TABLE 1.—*Comparison of chemical and burning treatments on the yield of reed canarygrass, Huntley, Mont., 1958–59*

Date of initial application and chemical or type of treatment	Application rate per acre		Yield per acre [2] [3]
	Weed oil [1]	Other chemicals	
Applied May 1958: [4]	*Gallons*	*Pounds*	*Tons*
Weed oil+PCP	100	1	0. 85 a
Weed oil	120		. 96 a b
Do	100		1. 39 a b
Diquat in water		2	1. 55 a b c
Weed oil+PCP	100	2	1. 65 b c
Diquat in water [5]		4	1. 69 b c
Weed oil	80		1. 84 c
None			3. 85 d
Applied May 1959: [4]			
Weed oil	120		. 58 a
Do	100		. 90 a b
Heavy burn			1. 45 b
Weed oil	80		1. 48 b
Diquat in water [5]		2	1. 53 b
Light burn			1. 57 b
Diquat in water [5]		2	1. 60 b c
Weed oil+PCP	100	2	1. 63 b c
Do	100	1	1. 65 c
None			4. 09 d

[1] Weed oil was an herbicidal oil containing 55 percent aromatics.
[2] Yield of reed canarygrass at end of growing season. Data are averages of 3 replications of each treatment.
[3] Duncan's multiple range test of significance at the 5-percent level. Treatments bearing the same letter were not significantly different.
[4] 2 additional applications were made during the growing season.
[5] Diquat applied in 100 gallons water with 1 percent nonionic wetting agent.

additives with the oil (table 2). The chemicals were applied on May 7, 1958, in herbicidal oil at 100 gallons per acre, when the grass was 2 feet tall. Amitrole and MH were dissolved in water and then emulsified with the oil by using 2 percent of a nonionic emulsifier. The effect of the treatments was visually estimated 1 month after applications were made.

The addition of the various growth inhibitors to the herbicidal oil generally resulted in greater control of reed canarygrass than the oil alone. Amitrole and dalapon, each at 10 pounds per acre with 100 gallons of herbicidal oil, were the best treatments. The addition of 10 pounds per acre of erbon or 5 pounds per acre of amitrole to the oil also gave satisfactory control. HCA, PBA, and CIPC as additives to the herbicidal oil gave slightly greater control of canarygrass than the oil alone, but these were considered unsatisfactory.

Growth inhibitors.—On June 17, 1959, the three most effective inhibitors from the 1958 experiment were again tested in comparison with amitrole-T (table 3). At this time the canarygrass was in the early-flowering stage. The chemicals were applied in water at 160 gallons per acre. Each treatment, except erbon, also contained 0.1 percent nonionic emulsifier. Each treatment was replicated three times.

TABLE 2.—*Comparison of seven growth inhibitors, when applied as additives to weed oil, for control of reed canarygrass, Huntley, Mont., 1958*

[Applications made May 7, 1958]

Chemical	Application rate of growth inhibitor, per acre [1]	Estimated control 4 weeks after treatment
		Percent
Weed oil + MH (diethanolamine salt)	4 pounds	80
Do	8 pounds	73
Weed oil + CIPC	4 pounds	63
Do	8 pounds	60
Weed oil + dalapon (diester)	5 pounds	80
Do	10 pounds	97
Weed oil + PBA (amine salt)	5 pounds	67
Do	10 pounds	53
Weed oil + amitrole	5 pounds	90
Do	10 pounds	100
Weed oil + HCA	1 gallon	63
Do	2 gallons	53
Weed oil + erbon	5 pounds	83
Do	10 pounds	90
Weed oil		50

[1] Weed oil at 100 gallons per acre was used as the diluent.

Dalapon and erbon treatments manifested maximum effect within 3 weeks after application (table 3); whereas, amitrole and amitrole-T treatments showed greatest effect 5 to 6 weeks after application.

Eight weeks after the treatments were applied, canarygrass was making regrowth on all plots. Amitrole-T at 6, 8, and 10 pounds of amitrole per acre gave the best control.

Soil sterilants.—Three groups of soil sterilants were tested for the control of reed canarygrass from 1958 to 1960.

In the fall of 1958, simazine, monuron, erbon, CBMM, and BMM were applied to a mature stand of reed canarygrass. They were applied in 200 gallons of water per acre. Treatments were not replicated.

Control of reed canarygrass was 100 percent for 2 years after treatment with simazine at 40 pounds per acre and monuron at 160 pounds per acre. Erbon, CBMM, and BMM also gave satisfactory control for 1 year after application. However, during the second year some reed canarygrass was becoming reestablished in these plots.

Another group of soil sterilants was applied in April 1959, when new growth of reed canarygrass was 6 inches high. Results showed that several soil-sterilant treatments gave 90 percent or more control of reed canarygrass for 4½ months after treatment (table 4). Atrazine at 25 pounds per acre and simazine at 15 pounds per acre were the only treatments giving 90 percent or more control one year after treat-

TABLE 3.—*Comparison of four systemic chemicals at four rates, for control of reed canarygrass, Huntley, Mont., 1959*

[Applications made June 17, 1959]

Chemical	Application rate per acre [1]	Estimated control [2] after—	
		3 weeks	8 weeks
	Pounds	*Percent*	*Percent*
Amitrole	2	43	60
Do	4	47	67
Do	6	63	77
Do	8	43	80
Do	10	43	83
Amitrole-T	[3] 2	40	83
Do	[3] 4	47	83
Do	[3] 6	47	87
Do	[3] 8	43	90
Do	[3] 10	50	90
Dalapon (sodium salt)	4	40	40
Do	8	57	53
Do	12	53	53
Do	16	57	57
Do	20	70	77
Erbon	20	40	30
Do	40	20	30
Do	80	83	57
Do	120	77	67
Do	160	77	67

[1] Water at 160 gallons per acre was used as the diluent.
[2] Data are averages of 3 replications of each treatment.
[3] Amount of amitrole.

ment. Reed canarygrass was rapidly reinfesting the other plots by the end of the first year.

A third group of soil sterilants was applied in May 1959 in central Montana. Erbon, TCA, and prometone were the only chemicals that gave a rapid topkill. Erbon and TCA treatments suppressed the growth of reed canarygrass for 6 to 8 weeks after application, but recovery was rapid after that time. Prometone at 20 pounds and granular simazine and granular atrazine at 25 pounds per acre suppressed the foliage growth for the rest of the season, about 12 weeks.

Observations made in August 1960 showed that the granular formulations of simazine and atrazine at 25 pounds per acre controlled 90 percent or more of the reed canarygrass. Equivalent rates of the wettable-powder formulations of these two herbicides were considerably less effective. As all of the debris had not been removed from the plots at the time of the application, it was assumed that some of the wettable-powder formulation was adsorbed onto or held by the debris; whereas, the dry-granular formulations were able to penetrate through the litter. The poor results obtained with the other wettable-powder formulations could have been caused the same way.

TABLE 4.—*Comparison of eight soil sterilants, at various rates, for control of reed canarygrass, Huntley, Mont., 1958–59*

[Applications made April 1959]

Chemical	Application rate per acre [1]	Estimated control after—	
		4½ months	1 year
	Pounds	*Percent*	*Percent*
Diuron	20	95	75
Do	40	100	75
Monuron	20	90	75
Do	40	95	75
Atrazine	15	90	50
Do	25	95	90
Simazine	15	95	98
Monuron-TCA	40	85	50
Erbon	80	80	10
Do	160	85	20
Dalapon + silvex [2]	16+4	70	10
Do	20+5	75	15
BMM	500	60	50
BMM	1, 000	70	50

[1] Water at 200 gallons per acre was used as the diluent.
[2] Diester of dalapon and polyethylene glycol butyl ether ester of silvex.

Summary

The results indicated that reed canarygrass on ditchbanks was effectively controlled by some soil-sterilant chemicals under favorable conditions. Leaching and waterflow in the wet part of the ditch limited the effectiveness of these treatments. Chemicals with low solubility in water, such as monuron, diuron, atrazine, and simazine, at heavy rates, were effective for 1 to 2 years under some conditions. Sodium chlorate, CBM, and fenuron gave seasonal control of reed canarygrass, but these are not practical treatments because of their short period of effectiveness and high cost. Most soil-sterilant treatments were also dependent on adequate and timely rainfall for best results. In some cases after vegetation had been killed high on the bank but where a fringe of grass survived at the waterline, the banks began to crack and slide into the canal (fig. 5). For these reasons the use of soil sterilants to control canarygrass on ditchbanks is questionable and must be considered with these limitations in mind.

Seasonal control of reed canarygrass was obtained with three applications of herbicidal oil at 100 or 120 gallons per acre. The addition of 10 pounds of dalapon or erbon or 5 or 10 pounds of amitrole per acre in 100 gallons of herbicidal oil was much more effective than oil alone. Amitrole-T at 6 to 10 pounds per acre in water was the most promising foliage treatment for control of reed canarygrass.

FIGURE 5.—A canal bank after treatment with monuron to control canarygrass (foreground) and untreated (background). Cracking and sloughing such as this often occur when the bank is denuded.

Quackgrass

Quackgrass (*Agropyron repens* (L.) Beauv.) is a perennial grass that spreads by underground rhizomes as well as by seed. This sod-forming grass with its dense growth of underground roots and rhizomes is a serious pest in irrigated lands, gardens, and nursery crops. Cultural and chemical methods of quackgrass control in croplands have been reported (*9*). Quackgrass is a moisture-loving plant. Frequently, moisture and soil conditions along irrigation delivery and drainage channels are favorable for the invasion of this grass. Infestations of quackgrass on the ditchbanks of such channels spread to adjacent farmlands.

Monuron was tested for quackgrass control in Washington from 1951 to 1956. Several chemicals were tested in Utah for control of this ditchbank weed.

Experiments in Washington

Early in September 1951, mature quackgrass and other debris on an irrigation ditchbank at Prosser, Wash., were burned. When regrowth of quackgrass was about 4 inches tall, a dense, uniform stand was selected and plots 10 by 10 feet were laid out in linear sequence.

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To avoid denuding the soil at the waterline by the treatments, only the upper part of the slope, the shoulder, and the top of the ditchbank were utilized in the plot layout. On October 15, four rates of monuron in 109 gallons of water per acre were applied in each of 4 randomized blocks (table 5). The topsoil was moist at the time of treatment.

Table 5.—*Comparison of rates of application of monuron for control of quackgrass, Prosser, Wash., 1951–56*

[Initial applications made Oct. 15, 1951; retreatments made Sept. 26, 1952]

Application rate per acre [1]		Estimated control [2] on—					
Initial	Total	May 20, 1952	Sept. 22, 1952	Dec. 6, 1953	Oct. 15, 1954	Sept. 15, 1955	May 8, 1956
Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10	20	44	61	86	93	95	94
20	40	92	91	98	90	100	97
40	40	99	99	98	98	99	94
80	80	99	99	99	96	99	98

[1] Water at 109 gallons per acre was used as the diluent.
[2] Data are averages of 4 replications.

Precipitation between October 15 and December 31 totaled 2.07 inches. Plots initially treated at the 10- and 20-pound rates were retreated at the same rates on September 26, 1952. No other retreatments were made.

The quackgrass reacted slowly to the applications of monuron. Significant evaluations of the treatments could not be made until May 1952 (table 5). From then to 1956, the two heavier rates gave almost 100 percent control. After retreatment in September 1952, the lighter rates were also highly effective.

Some growth of quackgrass was evident in the treated plots each year, especially in the spring. However, within a few weeks, the new plants showed typical symptoms of monuron toxicity (a form of chlorosis) and died.

In 1954 and 1955, Russian-thistle (*Salsola kali* L.) and other annual weeds began to invade the treated plots. By fall of 1956, Russian-thistles had grown to 4½ feet in height and were too dense to permit final estimates of quackgrass control.

Experiments in Utah

Experiments on control of quackgrass in small irrigation ditches were initiated near Logan, Utah, in April and in December 1951.

Spring application.—The initial applications were made in April 1951. Monuron, TCA, and sodium chlorate at various rates were compared (table 6). These chemicals were applied to 15- x 18-foot plots that extended across a quackgrass-infested irrigation head ditch and into the edge of an alfalfa field. The alfalfa field was irrigated

twice during the season, and water flowed through the head ditch for each of these irrigations.

All plots were retreated May 2, 1952. However, on the plots initially treated with monuron, only surviving quackgrass was retreated. The plots treated with TCA and sodium chlorate received full retreatment.

Observations made April 29, 1952, showed that the initial applications of monuron reduced the stand of quackgrass by 85 to 100 percent. The surviving grass was on the lower banks and bottom of the ditch. Elimination was complete on the upper banks and on the field edge. TCA and sodium chlorate gave good quackgrass control on the upper ditchbank and in the field margin, but were much less effective than monuron in controlling quackgrass on the ditch bottoms.

Observations made May 22, 1952, and August 17, 1953, showed that the initial applications of monuron at 40, 60, and 80 pounds per acre in April 1951, plus light retreatments made in the spring of 1952, had maintained almost complete control of quackgrass (fig. 6).

FIGURE 6.—A small irrigation ditch after treatment with monuron at 60 and 80 pounds per acre to control quackgrass (foreground and middle area); untreated (background).

Repeated applications of TCA or sodium chlorate had killed most of the quackgrass on the edge of the field and on the ditchbanks; but these treatments had reduced the stand very little in the ditch bottom, where quackgrass causes most interference with flow of the water (fig. 7).

TABLE 6.—*Comparison of three chemicals, at various rates, for control of quackgrass, Utah State Agricultural College Dairy Farm, Logan, Utah, 1951–53*

[Initial applications made Apr. 6, 1951; retreatments made May 2, 1952]

Chemical	Application rate per acre [1]			Stand reduction [2]—						
	Initial	Retreatment	Total	Apr. 29, 1952	May 22, 1952			Aug. 17, 1953		
					Ditchbank	Ditch bottom	Field	Ditchbank	Ditch bottom	Field
	Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Monuron	20	13. 5	33. 5	85	99+	82	100	99	78	99+
Do	40	6. 4	46. 4	98. 5	99+	99	100	100	99	95
Do	60	2. 8	62. 8	99. 5	99+	100	100	100	100	92
Do	80	1. 1	81. 1	100	100	99+	100	100	100	98
TCA	160	320	480	27	77	5	97	60	2	96
TCA	320	320	640	32	85	15	95	65	7	95
Sodium chlorate	480	480	960	35	96	2	37	92	20	37
Do	800	800	1, 600	60	99	5	95	99+	22	94
None	----	----	----	0	0	0	0	0	0	0

[1] All chemicals applied in water: Monuron and TCA, 240 gallons per acre; sodium chlorate, 480 gallons per acre.
[2] Data are averages at 2 replications.

Figure 7.—A small irrigation ditch after treatment with sodium chlorate at 480 and 800 pounds per acre to control quackgrass (foreground and middle area) and untreated (background). This treatment gave good kill on the ditchbank but poor kill in the bottom.

Fall application.—The initial applications were made in December 1951. Monuron was applied at 10, 20, 30, 40, and 50 pounds per acre; sodium chlorate at 480, 720, and 960 pounds per acre; and CBM at 960, 1,440, and 1,920 pounds per acre. The topgrowth on the plots was burned in November 1951. Heavy snows fell soon after burning and remained on the area. Herbicide applications were finally made on the snow in December, at which time 4 to 12 inches of snow were present.

All plots were retreated in October 1952 with the same herbicide as was used in the initial application. Those plots initially receiving the 50-pound treatment of monuron were spot treated. All other plots initially treated with monuron received a uniform retreatment of 20 pounds per acre. All sodium chlorate plots received a uniform retreatment of 720 pounds per acre. The CBM plots received a uniform retreatment of 960 pounds per acre.

Monuron was not so effective when initial applications were made in December 1951 as when they were made in April 1951. In this experiment total applications of 50 pounds per acre or more of monuron in 1951 and 1952 maintained good control through 1953 on ditchbanks and in the field, but the quackgrass showed about 50 percent recovery in the bottom of the ditch by August 1953. The ditch bottom eroded after the spray applications were made, and it was

believed that the herbicide applied to the ditch bottom had probably been removed with the eroded soil or by leaching.

Total applications of sodium chlorate of 1,200 to 1,680 pounds per acre gave better control of quackgrass than did monuron in this test. Stand reductions on August 17, 1953, ranged from 75 to 95 percent for the different rates of chlorate. The CBM at rates of 1,920 to 2,880 pounds per acre applied in two applications was less effective than sodium chlorate and also less effective than monuron in all situations except the ditch bottom.

Summary and Conclusions

The experimental results indicated that monuron at rates of 20 to 40 pounds per acre was one of the most effective soil treatments for the control of quackgrass on the banks and in the bottoms of irrigation ditches. Although retreatments were necessary, sodium chlorate, sodium salt of TCA, and CBM also were rather effective in controlling quackgrass on the ditchbanks and along the field margins. However, these more soluble herbicides apparently were leached from the soil too rapidly by passing water to be effective in the bottom of the ditches.

The removal of quackgrass topgrowth and other debris before applying monuron or the other soil sterilants is a good practice.

Monuron or the other soil sterilants should be applied in the fall or prior to a period of high precipitation.

The use of monuron or the other soil sterilants that destroy all vegetation is hazardous on ditchbanks subject to erosion.

Carex

Several species of Carex are troublesome on irrigation ditchbanks. These species are collectively known by the common names bullgrass, ripgutgrass, and Carex. These plants spread by extensive rhizomes or stolons and by seed. They are especially well adapted to the moist situation found at the waterline in ditches. Carex plants transpire large amounts of water, and, more important, they cause deposition of silt in the ditches. They gradually crowd into the ditch upon these silt bars and reduce water movement through the ditch. Carex infests many miles of ditchbanks in Montana, Wyoming, Utah, Idaho, Colorado, Nebraska, and the Dakotas.

Experiments in Wyoming

Four experiments on the control of Carex (*Carex lanuginosa* Michx.) were conducted near Torrington, Wyo., from 1955 to 1959. Growth-inhibiting, contact, and soil-sterilant herbicides, and burning with a liquid propane weed burner for 3 minutes per square rod at various intervals were compared.

The plots were arranged end to end along the canal bank and included the Carex growing in the edge of the water. The plots usually extended outward one-half rod from the waterline. Plot length ranged from 16.5 to 33 feet. All treatments were replicated two or three times in each experiment.

Spray applications were made with a knapsack sprayer fitted with a single-nozzle, wand-type boom. All herbicides applied as sprays were applied in a total volume of 120 gallons per acre; water, water and diesel oil emulsion, or diesel oil was used as the diluent. Chemicals used in dry form were applied by hand from a jar having a perforated lid.

Visual estimates of percentage control were made periodically during the growing season to determine effects of the treatments.

Exploratory experiment (1955).—Thirteen chemical and burning treatments for the control of Carex were compared in this exploratory experiment.

Burning, dalapon at 20 and 40 pounds per acre, amitrole at 10 and 20 pounds per acre, and DNBP-fortified fuel oil were initially applied July 12, 1955. Dalapon and amitrole were applied in a water and diesel oil emulsion containing 5 gallons per acre of diesel oil plus 2 percent nonionic emulsifier. The soil-sterilants monuron at 40 and 80 pounds per acre and BMM at 432 and 880 pounds per acre were applied October 21, 1955. Erbon at 80 and 160 pounds per acre and the diethanolamine salt of 2,4-D at 80 pounds per acre were initially applied May 24, 1956.

Observations made in the spring of 1956 showed that amitrole at 10 and 20 pounds per acre controlled 88 and 99 percent of the Carex, respectively. Analysis of the data showed amitrole at either rate to be significantly better than any of the other treatments. Dalapon at 20 and 40 pounds per acre controlled 67 and 78 percent of the Carex, respectively. Results after the first year showed that neither burning nor DNBP-fortified fuel oil had reduced the Carex stand.

Final results of this experiment were obtained July 9, 1957. Applications of the diethanolamine salt of 2,4-D applied at 80 pounds per acre on May 24 and July 18, 1956, plus a spot treatment May 22, 1957, completely eliminated the Carex (fig. 8). The Carex was replaced naturally with a desirable dense stand of Kentucky bluegrass from the thin stand of bluegrass which was mixed with the Carex before the chemical treatments.

Four spray applications of amitrole on July 12, 1955, May 24 and July 18, 1956, and June 5, 1957, at rates of 20, 10, 10, and 10 pounds per acre, respectively, reduced the Carex stand 99 percent and killed all of the bluegrass (fig. 9). Amitrole, applied at half this rate on the same dates eliminated 87 percent of the Carex in 2 years and grass did not become established.

Four spray applications of dalapon on the same dates as amitrole at two series of rates—20, 10, 20, and 10 pounds per acre and 40, 20, 40, and 20 pounds per acre, totaling 60 and 120 pounds per acre, respectively—reduced the stand of Carex 88 percent. However, the recovery during 1955 and 1956 was greater than from 2,4-D or amitrole treatments. Both dalapon and amitrole treatments permitted invasion of broad-leaved weeds as the stand of Carex was reduced. All amitrole and dalapon plots were treated with the diethanolamine salt of 2,4-D at 2 pounds per acre, once in 1956 and again in 1957, to control the broad-leaved weeds.

Five applications of DNBP-fortified fuel oil on July 12, 1955, May 24 and July 7, 1956, and June 5 and July 9, 1957, gave adequate

FIGURE 8.—An irrigation canal bank with a desirable stand of bluegrass that replaced naturally the Carex after two treatments with 2,4-D at 80 pounds per acre (left) and untreated (right).

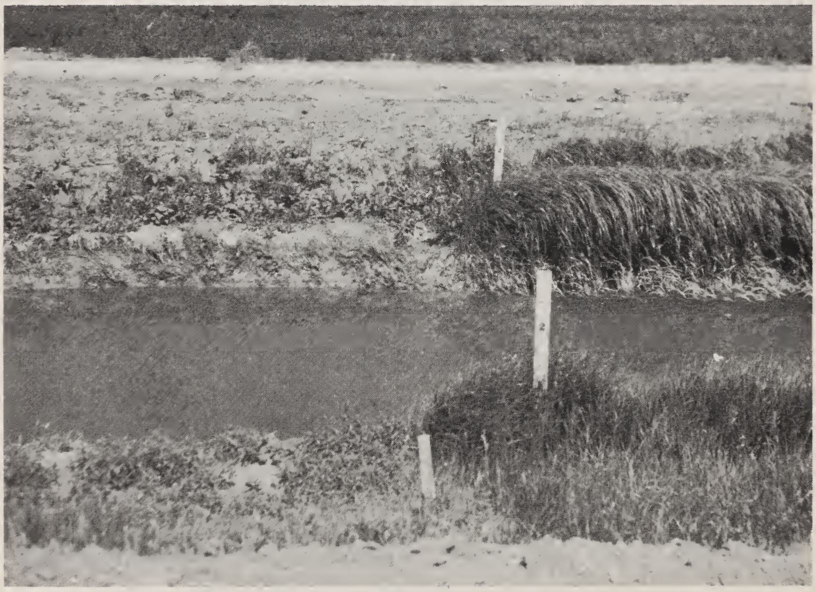

FIGURE 9.—A canal bank after repeated treatments with amitrole, at 10 pounds per acre, to control Carex (left) and untreated (right).

seasonal control of vegetation and eventually reduced the Carex stand 88 percent. Repeated burnings with a propane weed burner on the same dates as the DNBP-fortified fuel oil was applied gave only fair seasonal control of Carex and reduced the stand only 23 percent in 2 years.

Erbon applied at 80 and 160 pounds per acre on May 25 and July 18, 1956, and again May 22, 1957, totaling 240 and 480 pounds per acre, gave only fair control of Carex in 1956 and early in 1957. However, by the fall of 1957, these treatments had reduced the Carex stand 93 and 98 percent, respectively.

Treatments with monuron at 40 and 80 pounds per acre on October 21, 1955, and May 22, 1957, totaling 80 and 160 pounds per acre, gave only fair control of Carex growing above the waterline and very little control at and below the waterline. Results with BMM applied at rates of 432 and 864 pounds per acre on the same dates that monuron was applied, totaling 864 and 1,728 pounds per acre, were similar to those obtained with monuron.

Observations of all plots were made in the fall of 1959, 2.5 years after the final treatments were made, to study the plant succession that had occurred.

The Carex had made very little recovery on the plots that had been treated with amitrole or 2,4-D. However, a dense stand of other weeds, mainly broad-leaved weeds, had developed on the plots treated with amitrole. On the plots treated with 2,4-D, a desirable stand of Kentucky bluegrass was still present and it had been effective in preventing reinfestation by Carex or invasion by other weeds.

On all other plots the Carex had recovered to a dense and vigorous stand at the waterline and to a medium-to-dense stand on the top and sides of the bank above the waterline. Wherever there was less than a complete stand of Carex, other weeds had invaded the bare areas. The combination of Carex and other weeds on these plots was reducing waterflow in the ditch 45 to 55 percent.

Rates of amitrole.—The purpose of this experiment was to test the feasibility of using lower rates of amitrole than had previously been used for the control of Carex.

Initial applications of amitrole at rates of 3, 6, and 9 pounds per acre were made May 25, 1956. The Carex was 6 to 10 inches high and in the flowering stage. Retreatments were made at the original rates on August 16, 1956. The amitrole was applied in a water and diesel oil emulsion containing 5 gallons of diesel oil per acre plus a nonionic emulsifier at 2 percent of the diesel oil.

Observations made in the fall of 1956 showed that the reduction in Carex stand was 92 percent from the 9-pound-per-acre rate of amitrole, 78 percent from the 6-pound-per-acre rate, and 60 percent from the 3-pound-per-acre rate. Control had diminished by June 30, 1957. At this time all plots were retreated at the initial rate except the 9-pound-per-acre treatment, which was spot treated only in August of that year.

Reduction of the Carex stand on June 10, 1958, was 55 percent with the 3- and 6-pound-per-acre rates and 80 percent with the 9-pound-per-acre rate of amitrole. These results show that for complete control of Carex with amitrole, applications must be made more

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than once each growing season when a rate of 9 pounds per acre or less is used.

Chemicals and burning.—This experiment was undertaken to find more effective and less expensive means of controlling Carex than burning and cutting. Treatments, application rates, retreatment dates, total chemical applied during 1957 and 1958, and results are shown in table 7. Initial treatments with the diethanolamine salt of 2,4-D, erbon, and BDM were applied May 15, 1957. All other initial treatments were made June 6, 1957.

Preliminary observations made September 4, 1957, showed that both 2,4-D treatments had a slight advantage over the erbon and BDM treatments. Two retreatments with amitrole were much more effective than one or no retreatments. The 5-pound-per-acre rate applied three times was as effective as the 20-pound-per-acre rate applied twice in the first year. Three and five applications of dalapon at 20 pounds per acre reduced the Carex 92 to 99 percent. Spraying with DNBP-fortified fuel oil was highly superior to burning at the same frequencies during the first year of treatment.

Control of Carex before retreatments were made in 1958 was approximately the same on most plots as it had been in the fall of 1957. Carex had made considerable recovery on plots treated with 2,4-D and erbon.

Observations made in the fall of 1958, the final year of the experiment, showed that good to excellent control of Carex over the 2-year period was obtained by repeated applications of 2,4-D and amitrole and by DNBP-fortified fuel oil applied every 3 weeks. There appeared to be a slight advantage for the heavier rate of 2,4-D. Final results with amitrole followed the first year's results very closely. Amitrole applied four times in 2 years at 5 pounds per acre gave control comparable with 10 or 20 pounds per acre applied three or four times, respectively, in the same 2 years. Amitrole applied at 20 pounds per acre only once each year resulted in less control of Carex than any of the other amitrole treatments.

In general, dalapon, erbon, BDM, spraying with DNBP-fortified fuel oil every 6 weeks, and burning gave only fair control of Carex throughout the experiment. All amitrole and dalapon plots were treated with 2,4-D at 2 pounds per acre on May 27, 1958, to control the broad-leaved weeds that had invaded the areas where the Carex had been eliminated. Erbon and BDM showed less control of Carex in the fall of 1958 than in the fall of 1957 even though retreatments were made in 1958.

The addition of diesel oil and emulsifier to amitrole and dalapon did not significantly increase the effectiveness of either.

Spraying with DNBP-fortified fuel oil every 6 weeks and burning with LP gas every 3 weeks finally resulted in good control of Carex in the latter part of the second year. Burning with LP gas every 6 weeks failed to give sufficient control of Carex at any time during the 2-year period. All burning was done with a single unit burner.

Amitrole alone and with surfactants.—This experiment was initiated June 20, 1957, to test the effect of diesel oil plus emulsifier and two wetting agents, in combination with amitrole, on the control of Carex. Treatments consisted of amitrole at 5 pounds per acre (1) alone, (2) plus 10 gallons per acre diesel oil and 0.4 gallon per

TABLE 7.—*Comparison of chemical and burning treatments for the control of Carex, Torrington, Wyo., 1957–58*

[Initial applications made in spring of 1957]

Chemical or type of treatment	Application rate per acre				Date of retreatments		Control [1] on dates given			
	Herbicide		Diluent				Top-kill,	Reduction in stand on—		
	Initial	Total	Water	Oil	1957	1958	June 21, 1957	Sept. 4, 1957	May 16, 1958	Sept. 25, 1958
	Pounds	*Pounds*	*Gallons*	*Gallons*			*Percent*	*Percent*	*Percent*	*Percent*
2,4-D	40	100	120		None	5/17 and 7/27	63	93	57	86
2,4-D	80	160	120		Do	5/17 and 7/27	87	94	76	95
Erbon	80	160	120		Do	5/17	77	87	20	71
Do	160	320	120		Do	5/17	82	88	53	74
BDM	533	1, 066	120		Do	5/17	72	92	83	63
Amitrole	5	20	114. 8	[2] 5	7/9 and 9/4	7/27	92	95	90	97
Do	10	30	120		8/8	7/2	83	72	85	99
Do	10	30	114. 8	[2] 5	8/8	7/2	85	67	89	95
Do	10	40	114. 8	[2] 5	7/9 and 9/4	7/2	90	97	98	99
Do	20	40	114. 8	[2] 5	None	7/2	92	88	85	91
Do	20	70	114. 8	[2] 5	8/8	5/17 and 7/2	88	87	91	97
Dalapon	20	80	120		7/9 and 9/4	7/2	60	92	97	58
Do	20	80	114. 8	[2] 5	7/9 and 9/4	7/2	67	98	95	69
Do	20	140	120		6/21, 7/9, 8/8, and 9/4.	7/2 and 8/14	75	98	96	93
Do	20	140	114. 8	[2] 5	6/21, 7/9, 8/8, and 9/4.	7/2 and 8/14	68	99	96	79
DNBP+fuel oil	1. 5	([3])		120	6/21, 7/9, 8/8, and 9/4.	5/17, 6/12, 7/2, and 7/27.	75	95	97	99
Do	1. 5	([4])		120	7/9 and 9/4	5/17, 7/2, and 8/14.	73	42	70	98
Propane burner:										
Every 3 weeks					6/21, 7/9, 8/8, and 9/4.	5/17, 6/12, 7/2, and 7/27.	47	73	79	97
Every 6 weeks					7/9 and 9/4	5/17, 7/2, and 8/14.	42	33	30	57

[1] Data are averages of 3 replications of each treatment.
[2] 5 gallons per acre diesel oil and 0.2 gallon per acre of emulsifier were added to the water.
[3] 27 pints of DNBP and 1,080 gallons of fuel oil.
[4] 18 pints of DNBP and 720 gallons of fuel oil.

acre nonionic wetting agent, (3) plus 2½ and 5 pounds per acre of sodium sulfonate of methyl and dimethyl naphthalene, and (4) plus 4 and 16 ounces of alkylarylopolyoxyethylene glycols.

Control of Carex ranged from 0 to 30 percent when observed May 26, 1958. At this time all plots were retreated as initially. Observations made in the fall of 1958 showed that Carex control ranged from 72 to 83 percent on all treated plots, with the amitrole applied alone giving the least control. Amitrole plus the wetting agent sodium sulfonate of methyl and dimethyl naphthalene at 5 pounds per acre tended to give the best control. However, the difference between treatments usually was small and apparently the addition of these wetting agents did not significantly improve the control of Carex by amitrole. This is in agreement with the results from adding diesel oil and emulsifier to certain amitrole treatments in the previous experiment.

Summary

Results of four experiments at Torrington, Wyo., during 1955 to 1959 indicated that the following chemical treatments were effective for control of *Carex lanuginosa:* 2,4-D at 40 to 80 pounds per acre applied three times in 2 years; amitrole at 5 or 10 pounds per acre applied three or four times in 2 years; and DNBP-fortified fuel oil at 120 gallons per acre applied at 3- to 6-week intervals for 2 years. Dalapon at 20 pounds per acre applied 2 to 4 times each year maintained control of Carex, but did not eliminate the stand.

There was no advantage in adding wetting agents to either amitrole or dalapon. Erbon, monuron, and a borate-monuron mixture were not effective on Carex.

An advantage for 2,4-D over other treatments was that when a thin stand of Kentucky bluegrass was present in the Carex the stand of bluegrass became denser and more vigorous as the stand of Carex was reduced by 2,4-D and prevented reinvasion of the area by Carex or other weeds after the 2,4-D treatments were terminated. Other chemical and burning treatments killed out the bluegrass along with the Carex and left the ditchbank bare and open for reinvasion of undesirable weeds.

PERENNIAL BROAD-LEAVED WEEDS

Canada Thistle

Canada thistle (*Cirsium arvense* L. Scop.) is a perennial noxious weed that propagates by creeping, freely branching roots and by seed. Irrigation and drainage ditchbanks are especially vulnerable to infestation by this weed. Once established, Canada thistle thrives on the dry shoulders and tops of ditchbanks as well as along the waterline and in the wet, seepage areas along the base of some backslopes (fig. 10).

Because of the vigorous habit of growth, sharp spiny leaves, and an unsightly appearance, especially after bloom, Canada thistle is a nuisance in almost any locality. This weed is particularly undesirable on agricultural land because it interferes with crop production and reduces crop yields. Canada thistle on ditchbanks is controlled

FIGURE 10.—An infestation of Canada thistle on an irrigation ditchbank, near Prosser, Wash.

not only because this weed is a menace to the ditchbanks but also because it is a menace to the adjacent farmlands and to the community. Cultivation and cropping systems that effectively control Canada thistle on cropland are not practical on ditchbanks. Thus, the use of chemicals is the best method for controlling this weed on ditchbanks. Certain soil-sterilant and growth-inhibitor herbicides were studied at two locations.

Experiments in Washington

Soil sterilants.—An experiment was initiated in 1949 near Prosser, Wash., on an irrigation ditchbank infested with Canada thistle. Each plot, 1-rod-square, extended from the top of the ditchbank to the waterline. The ditchbank consisted of windblown, fine-textured soil materials admixed with a high proportion of basalt rock, stone, and coarse gravel. On October 25, soil-sterilant herbicides were applied at random in three blocks as follows:

	Pounds per square rod
Sodium chlorate (spray)	4, 5, 6, and 8
Sodium chlorate (dry)	4, 5, 6, and 8
A proprietary compound, containing approximately 60 percent sodium chlorate (spray)	6, 8, 10, and 12
CBM (dry)	6, 9, 12, and 15
Soluble sodium borate, containing 66.6 percent B_2O_3 (dry)	10, 15, 20, and 25

Materials applied in the dry form were broadcast by hand. Sprayed materials were applied with a small power sprayer. One gallon of water was used for every 1 or 1½ pounds of herbicide. Rainfall was sufficient shortly after application to dissolve the herbicides applied in the dry form. The average annual precipitation for the area is about 7.5 inches.

In 1950, 1951, and 1952, spot retreatments (herbicides applied within a 6-inch radius around individual surviving shoots) were made on the top and shoulder of the ditchbank as necessary at rates approximately as follows:

	Pounds per 50 shoots
Sodium chlorate	1
Proprietary compound (60 percent sodium chlorate)	1½
CBM	2
Soluble sodium borate	3

In the 3-foot margin just above the waterline, blanket retreatments usually were made. However, spot retreatments generally were made if survival did not exceed 30 shoots per square rod.

One block of plots was seeded each fall, in 1951, 1952, 1953, with a mixture of grasses at the rate of 10 pounds per acre. Each plot within the block was seeded separately with a mixture composed of smooth bromegrass, crested wheatgrass, Kentucky bluegrass, creeping red fescue, and redtop. After seeding, the plots were handraked lightly to incorporate the seed with the soil.

The initial treatments were highly effective on the top and shoulder of the ditchbank. Survival of Canada thistle after 1 year ranged from 0 to 5 shoots per square rod. These surviving shoots were weak and chlorotic; hence, only an occasional spot retreatment in the fall of 1950, 1951, and 1952 was needed to eradicate them on plots treated with the sodium chlorates, CBM, and the 25-pound rate of soluble sodium borate. With the exception of the soluble borate, all rates of application were about equally effective. The soluble borate at 10, 15, and 20 pounds per square rod plus spot retreatments was somewhat less effective than the other herbicides and failed to eliminate the Canada thistle.

The 2- to 3-foot margin immediately above the waterline proved to be the greater problem area. The initial treatments plus spot or blanket retreatments failed to eliminate or satisfactorily control the Canada thistle along this margin. The excessive moisture in this saturated and capillary zone of the ditchbank apparently reduced the effectiveness of the chemicals on the deep-rooted Canada thistle.

The application of soil sterilants along the margin immediately above the waterline introduced another problem. The soil was denuded of thistle topgrowth and other vegetation for sufficient lengths of time to cause severe scouring, or erosion, of the ditchbank, especially in the curves or bends of the irrigation channel (fig. 11).

The grasses seeded on the treated plots in 1951, 1952, and 1953 failed to become established on the top and shoulder of the ditchbank. Through general field spraying by irrigation project personnel, the area was treated with 2,4-D at least twice a year from 1954 through 1959. Ten years after the initial application of soil sterilants, the top and shoulder of the ditchbank generally remained bare of vegeta-

FIGURE 11.—Erosion of a ditchbank at the bend of an irrigation channel, near Prosser, Wash., after treatment with chlorates and borates to control Canada thistle.

tion (fig. 12). However, grasses and other vegetation became established in the 3- to 4-foot zone above the waterline. For Canada thistle on irrigation systems, soil sterilants apparently can be used most advantageously for eliminating small infestations on the tops and shoulders of ditchbanks.

Growth inhibitors.—An experimental test for comparing growth inhibitors was initiated in 1950. The site was located on the ditchbank opposite the soil-sterilant experiment. Each treatment was replicated three times on plots 1-rod-square that extended from the top of the ditchbank to the waterline. Initial shoot counts, which ranged from about 50 to 450 per square rod, were taken on each plot and served as a basis for determining the percentage reduction in stand caused by the treatments. On June 8, at which time the Canada thistle growth was mostly in the full-bud stage, certain formulations of 2,4-D, 2,4,5-T, and MCPA were applied within each block (table 8.). Retreatments of the same rates as the initial treatments were made on September 14, 1950, and June 8, 1951.

The initial spring treatments in 1950 failed to give completely satisfactory control of the topgrowth of Canada thistle (table 8).

FIGURE 12.—The top and shoulder of a ditchbank, near Prosser, Wash., after treatment with chlorates and borates to control Canada thistle (right) and untreated (left). Photographed 10 years after treatment.

Some of the treated growth recovered sufficiently to bloom before retreatments were made in September. Moreover, new shoots were emerging within 3 days after the initial treatments. These developments suggested the possible need of more than two treatments per year.

The number of plant shoots was reduced 45 to 91 percent after retreatments on September 14, 1950. Likewise, after retreatments on June 8, 1951, some additional reduction in shoots occurred.

The alkanolamine salt of 2,4-D and the amine salt of MCPA appeared fully as effective as the ethyl and butoxy ethanol esters of 2,4-D in controlling Canada thistle. On September 25, 1951, the dimethylamine salt was the least effective of the 2,4-D formulations. No advantage was apparent in applying 2,4,5-T in a mixture with 2,4-D. The effectiveness of the alkanolamine salt of 2,4-D was not increased in this experiment by the addition of diesel oil or nontoxic oil.

With the possible exception of the butoxy ethanol ester of 2,4-D and one mixture of 2,4-D and 2,4,5-T, the effectiveness of repeated applications at the 2-pound rate did not differ greatly from that of repeated applications at the 4-pound rate. The alkanolamine salt of 2,4-D was as effective in 40 as in 80 gallons of water per acre. However, this formulation was less effective when applied in 3 or 8 gallons of water per acre.

Previous to the treatments, the vegetative growth was predominantly Canada thistle and only sparse stands of redtop, bluegrass, and other grasses were present. After treatments with the various formulations of 2,4-D, 2,4,5-T, and MCPA, dense stands of these grasses developed, which offered strong competition for seedlings and surviving shoots of Canada thistle (fig. 13).

TABLE 8.—*Comparison of certain formulations of 2,4-D, 2,4,5-T, and MCPA for control of Canada thistle, near Prosser, Wash., 1950–51*

[Initial applications made June 8, 1950; retreatments made Sept. 14, 1950, and June 8, 1951]

Chemical	Application rate per acre				Reduction in number[1] of shoots on—		
	Acid equivalent		Diluent				
	Initial	Total	Water	Oil	Sept. 14, 1950	June 8, 1951	Sept. 25, 1951
	Pounds	*Pounds*	*Gallons*	*Gallons*	*Percent*	*Percent*	*Percent*
Ethyl ester of 2,4-D	2	6	40	------	0	69	88
Do	4	12	40	------	2	72	82
Butoxy ethanol ester of 2,4-D	2	6	40	------	6	59	77
Do	4	12	40	------	35	86	91
2:1 mixture of butoxy ethanol ester of 2,4-D and 2,4,5-T[2]	2	6	40	------	0	45	55
Do[2]	4	12	40	------	0	65	87
Do[3]	2	6	40	------	46	77	93
Do[3]	4	12	40	------	25	75	91
Dimethylamine salt of 2,4-D	2	6	40	------	0	63	67
Triethanolamine salt of MCPA	2	6	40	------	58	88	94
Do	4	12	40	------	46	86	88
Alkanolamine salt of 2,4-D	2	6	40	------	0	69	91
Do	4	12	40	------	44	89	96
Do	2	6	80	------	23	69	86
Do	2	6	3	------	19	61	68
Do	2	6	8	------	33	60	72
Alkanolamine salt of 2,4-D and diesel oil[4]	2	6	38	2	45	77	78
Do	4	12	38	2	63	91	88
Alkanolamine salt of 2,4-D and nontoxic oil[4]	2	6	38	2	60	74	84
Do	4	12	38	2	30	70	85

[1] Data are averages of 3 replications of each treatment.
[2] Mixture consisted of 1⅓ pounds of 2,4-D and ⅔ pound of 2,4,5-T per gallon.
[3] Mixture consisted of ⅔ pound of 2,4-D and ⅓ pound of 2,4,5-T per gallon.
[4] Oil-water emulsifier was added at the rate of 1 quart per 100 gallons of spray.

In cooperation with the Roza Irrigation Field Division, Bureau of Reclamation, a field trial was initiated in May 1957. This trial was conducted on a 3-mile section (both banks) of the main canal, between Mile Stations 73 and 76 . The Roza Division furnishd the materials, spray equipment, and personnel for making the treatments.

To minimize the hazard of spray drift, the hydraulic boom on the spray unit was equipped with fan-type nozzles having at least 1/16-inch orifices and the working pressures were limited to 20 or 25 p.s.i. A volume of 60 gallons of water per acre containing a wetting agent was used as the diluent.

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FIGURE 13.—Desirable grassy vegetation on irrigation ditchbanks near Madras, Oreg.; this offers effective competition against weeds.

This trial was designed to obtain information on scheduling initial and followup treatments of 2,4-D for control of Canada thistle under field conditions. Results of experimental applications of 2,4-D to control Canada thistle had indicated that treatment should be made during the early-bud stage of growth for best control. Ditchbank infestations of this weed are often quite variable in stage of growth, which makes it impossible to spray when all plants are in the desired growth stage. Also it is impractical for irrigation projects to own or operate enough equipment to treat extensive infestations on large irrigation systems within the short period of greatest sensitivity.

The first treatment was made on May 24, 1957, at which time a few of the thistle shoots were beginning to bloom and others were still emerging. An iso-octyl ester of 2,4-D was applied at the rate of 3 pounds per acre. Excellent topkill of thistle shoots was obtained, especially of those shoots that had not reached the full-bloom stage at the time of treatment. However, new shoots continued to emerge after the application.

New and surviving growth of Canada thistle was sufficient to warrant a retreatment on July 26, 1957. A dimethylamine salt of 2,4-D at 3.6 pounds per acre was used for the retreatment, because even low-volatile esters of 2,4-D are somewhat hazardous to susceptible crops under very high temperatures. Five gallons of diesel oil and 1 cup of oil-water emulsifier per 100 gallons of water were added because the thistle had become less succulent and more hardy during

the hot summer months. Good control was maintained until late in September, at which time some new shoots had emerged in scattered sections. This new growth appeared to justify a third treatment, which was made early in October without oil in the mixture.

After the three sprayings in 1957, only an occasional Canada thistle shoot survived on the top and shoulder of the ditchbanks on May 5, 1958. A few shoots survived at the waterline, especially where the banks were steeply sloped and good coverage of these shoots during spraying was difficult.

The section was resprayed with the dimethylamine salt of 2,4-D on May 26, 1958, when many of the surviving shoots were in the early-bud stage and some were still emerging. Because spot retreatment was considered impractical, the entire 3-mile section was retreated, with diesel oil in the mixture, on July 22 and October 1 to control the few scattered shoots that remained. These were mostly at the waterline, some standing in water 3 to 4 inches deep. Other types of broad-leaved weeds were controlled also by these treatments, whereas grasses and horsetail rush (*Equisetum arvense* L.), a much more desirable plant on ditchbanks in this area than Canada thistle, thrived.

The experimental and field trial results support the conclusion that three sprayings with 2,4-D per year are needed to most effectively control and reduce the stand of Canada thistle on ditchbanks in the irrigated sections of Washington. Moreover, on a project basis, each spraying operation apparently should be started early enough to cover all infestations before the bloom stage is reached.

2,3,6-TBA and PBA.—The experiment was initiated on a small irrigation delivery channel near Prosser, Wash. The treatments were replicated three times. Each plot was 16½ feet long and extended 8¼ feet outward from the waterline on opposite ditchbanks, equaling 1 square rod. These ditchbanks consisted of windblown, fine-textured soil materials interspersed with a low proportion of basalt rock and gravel.

The stand of Canada thistle was not dense but fairly uniform. Initial shoot counts were taken as a basis for evaluating the effectiveness of the treatments. Dimethylamine salts of 2,3,6-TBA and of PBA at four rates were applied at random within each block on November 4, 1958. Some of the thistle topgrowth was still green and the rest was partially or wholly desiccated. All chemicals were applied with a 3-gallon knapsack sprayer; water was used as the diluent at the rate of 320 gallons per acre. All plots were retreated at the same rates on September 28, 1959.

When observations of these treatments were made on May 28, 1959, all surviving shoots showed severe symptoms of injury, i.e., pale coloration and malformation. Most of the surviving shoots still exhibited injury symptoms as late as September 28. The 40-pound rate of the dimethylamine salt of 2,3,6-TBA gave the most consistent and effective results (table 9). Pound for pound, the dimethyalmine salt of PBA was about half as effective as the same salt of 2,3,6-TBA after one treatment. None of the treatments appreciably suppressed the growth of Kentucky bluegrass in the plots during 1959.

Most of the shoots of Canada thistle that survived the treatments were in the wet zones near the waterline. These shoots were delayed

in emergence, but they showed no appreciable injury symptoms. The few surviving shoots in the dry zones of the ditchbank were mostly weak, chlorotic, and severely malformed. Experience with formulations of 2,3,6-TBA and PBA on other deep-rooted perennial weeds suggests the possibility of additional emergence of an occasional shoot from considerable depths later in the season. After the retreatments in September 1959, both compounds at the two heaviest rates injured the Kentucky bluegrass rather severely.

TABLE 9.—*Comparison of dimethylamine salts of 2,3,6-TBA and of PBA, at various rates, for control of Canada thistle, near Prosser, Wash., 1958–60*

[Initial applications made Nov. 4, 1958; retreatments made Sept. 28, 1959]

Chemical	Application rate per acre [1]		Reduction [2] in number of shoots on—		
	Initial	Total	May 28, 1959	Sept. 28, 1959	June 2, 1960
	Pounds	*Pounds*	*Percent*	*Percent*	*Percent*
Dimethylamine salt of 2,3,6-TBA	5	10	6	34	94
Do	10	20	40	41	99+
Do	20	40	13	68	99
Do	40	80	71	94	100
Dimethylamine salt of PBA	10	20	0	0	87
Do	20	40	92	77	97
Do	40	80	28	58	98
Do	80	160	57	39	99+

[1] Water used as a diluent at the rate of 320 gallons per acre.
[2] Data are averages of 3 replications of each treatment.

Summary

Results of a ditchbank field trial in Washington with 2,4-D indicated that three sprayings per year with 2 to 4 pounds per acre were needed to most effectively control and reduce the stand of Canada thistle, because of the variable and almost continuous emergence of new shoots throughout the season Six spray applications in 2 years eliminated all Canada thistle except widely scattered plants mostly at the waterline and provided excellent control of other broad-leaved weeds. Desirable grasses such as redtop and bluegrass increased after these treatments and provided competition with surviving Canada thistle shoots and new seedlings.

The alkanolamine salt of 2,4-D was as effective as the ethyl ester; all formulations of 2,4-D and MCPA were about as effective at 2 pounds as at 4 pounds per acre. Mixtures of 2,4-D and 2,4,5-T were no more effective than 2,4-D alone. There was no advantage in adding diesel oil or nontoxic oil to spring and fall applications of the alkanolamine salt of 2,4-D.

Excellent control of Canada thistle was obtained with 2,3,6-TBA. Two annual applications of PBA at 20 to 80 pounds per acre nearly eliminated the stand of Canada thistle.

Sodium chlorate and CBM gave excellent control of Canada thistle on the top and shoulder of ditchbanks in Washington. However, near the waterline the chemicals were rather ineffective and caused erosion.

Waterhemlock

Waterhemlock *(Cicuta* spp.) grows near the waterline on numerous ditchbanks of delivery and drainage channels in the irrigated sections of the West. It thrives and spreads exceptionally well on ditchbanks where weeds are controlled by burning and mowing. This tall-growing perennial not only increases the cost of ditchbank maintenance but is also poisonous to livestock.

Experiment in Washington

In 1958 to 1960, three series of treatments for the control of waterhemlock were made on an irrigation ditchbank near Prosser, Wash. The ditchbank vegetation was burned early in the spring and mowed twice during the summer each year in 1958 and 1959. Herbicide treatments were made on 16.5- by 4-foot plots just above and parallel to the waterline in three randomized blocks.

In 1958 and 1959 the regrowth of waterhemlock from previous mowing was 18 to 24 inches high when the herbicides were applied. In 1960, the alkanolamine salt of 2,4-D was applied after early-spring burning but prior to the first seasonal mowing of the ditchbank. The waterhemlock averaged about 2 feet in height at this time.

All herbicides were applied with 3-gallon knapsack sprayers. Water was used as the diluent at the rate of 80 gallons per acre. Appropriate amounts of polyoxyethylene sorbitan monolaurate were added as a wetting agent.

Counts of waterhemlock were made on all plots just prior to the initial treatments and periodically thereafter to determine the effectiveness of the herbicidal applications (table 10). Suppression of grasses by the treatments was observed also.

The results obtained with the various herbicides can be summarized as follows.

2,4-D.—The alkanolamine salt of 2,4-D effectively reduced the stands of waterhemlock when applied on September 15, 1958. The 4-pound rate appeared somewhat more effective than the 1- and 2-pound rates. However, all rates eliminated the waterhemlock after retreatments on August 28, 1959.

Initial applications of the alkanolamine salt of 2,4-D on June 3, 1960, likewise, were highly effective in reducing or eliminating the stands of waterhemlock. The grass stand was not reduced by 2,4-D treatments.

2,3,6-TBA.—The dimethylamine salt of 2,3,6-TBA at 4, 8, and 12 pounds per acre was ineffective on waterhemlock. At these rates, the treatments caused no apparent suppression of the grasses.

2,4,5-T.—One application of the glycol butyl ether ester of 2,4,5-T at 1, 2, or 4 pounds per acre on August 28, 1959, gave 100 percent

TABLE 10.—*Comparison of several chemicals, at various rates, for control of waterhemlock near Prosser, Wash., 1958–60*

Date of initial application and chemical	Application rate per acre [1]		Plants per 66 square feet			
				Surviving on—		
	Initial	Total	Initial, Sept. 15, 1958	May 7, 1959	Aug. 28, 1959	June 3, 1960
Sept. 15, 1958:	*Pounds*	*Pounds*	*Number*	*Number*	*Number*	*Number*
Alkanolamine salt of 2,4-D [2]	1	2	9	2	3	0
Do. [2]	2	4	11	1	3	0
Do. [2]	4	8	12	0	1	0
Amitrole	2	2	11	6	7	-------
Do	4	4	13	4	8	-------
Do	8	8	18	2	8	-------
Erbon	40	40	10	5	8	-------
Do	80	80	12	4	6	-------
Do	120	120	14	6	8	-------
4:1 mixture of esters of dalapon and silvex	5	5	16	9	7	-------
Do	10	10	14	8	7	-------
Do	15	15	12	8	8	-------
Dimethylamine salt of 2,3,6-TBA	4	4	13	9	9	-------
Do	8	8	15	9	10	-------
Do	12	12	13	9	7	-------
None	0	0	12	6	8	11
			Aug. 28, 1959	June 3, 1960		Sept. 6, 1960
Aug. 28, 1959:						
Glycol butyl ether ester of 2,4,5-T	1	1	9	0	-------	0
Do	2	2	10	0	-------	0
Do	4	4	7	0	-------	0
1:2 mixture of the tetrahydrofurfuryl esters of 2,4,5-T and 2,4-D [3]	1	2	7	1	-------	0
Do. [3]	2	2	8	0	-------	0
Do. [3]	4	4	8	0	-------	0
Propylene glycol butyl ether ester of silvex [3]	1	2	7	6	-------	4
Do. [3]	2	4	7	1	-------	0
Do. [3]	4	8	8	1	-------	0
None	0	0	8	6	-------	9
			June 3, 1960	July 29, 1960		Sept. 6, 1960
June 3, 1960:						
Alkanolamine salt of 2,4-D	1	1	5	0	-------	0
Do	2	2	8	0	-------	0
Do	4	4	9	0	-------	1
None	0	0	6	9	-------	9

[1] Water used as the diluent at the rate of 80 gallons per acre. [2] Retreated Aug. 28, 1959.
[3] Retreated June 3, 1960, unless eradication was completed.

control of waterhemlock as recorded on June 3 and September 6, 1960. No injury to the grasses was apparent.

Esters of 2,4,5-T and 2,4-D.—A 1:2 mixture of the tetrahydrofurfuryl esters of 2,4,5-T and 2,4-D at 1, 2, and 4 pounds per acre was highly effective on waterhemlock when applied on August 28, 1959. As observed on June 3, 1960, one plant per 66 square feet survived the 1-pound treatment, but no plants survived the 2- and 4-pound applications. Grasses were unaffected.

Silvex.—The propylene glycol butyl ether ester of silvex at 1 pound per acre was ineffective on waterhemlock when applied on Aug. 28, 1959. However, the 2- and 4-pound rates were highly effective in reducing the stands. After retreatments on June 3, 1960, no waterhemlock survived the 2- and 4-pound applications, but four plants per 66 square feet survived the 1-pound treatments. No effect on the grasses was noted.

Amitrole.—Although the September applications of amitrole at 2, 4, and 8 pounds per acre caused some delay in emergence of waterhemlock the following spring, the stands were not reduced appreciably by the treatments. The 4- and 8-pound rates caused some injury to the grasses.

Erbon.—Erbon at 40, 80, and 120 pounds per acre was not considered effective in reducing the stand of waterhemlock. In addition, a high percentage of the grasses was killed by the treatments.

Esters of dalapon and silvex.—The 4:1 mixture of esters of dalapon and silvex at 5, 10, and 15 pounds per acre showed little promise in controlling waterhemlock. However, this mixture showed real promise as a grass suppressant.

Summary

Waterhemlock apparently is sensitive to 2,4-D and 2,4,5-T. This poisonous plant was eliminated from ditchbanks of irrigation channels most effectively with one or two applications of either compound at rates of 1 or 2 pounds per acre per treatment. Initial late-spring or early-summer applications were slightly more effective than initial late-summer or early-fall treatments that followed summer mowing operations.

MISCELLANEOUS DITCHBANK WEEDS AND GRASSES

Miscellaneous vegetation growing on small farm ditches interferes with water delivery and increases maintenance costs as well as water loss. Such vegetation is frequently composed of annual, biennial, and perennial grasses and weeds. Complete removal of the vegetation is often undesirable or unnecessary. Certain perennial grasses prevent erosion and destruction of ditchbanks, but rank growth of such grasses frequently interferes with water delivery in the ditches. Control of this vegetation by mowing has not been very efficient, and control by hand scything is tedious and time consuming. Control by chemicals that suppress plant growth and those that cause plant kills were found to be effective as well as practical.

Experiment in Idaho

An experiment was begun June 1, 1948, to test two herbicidal oils and diesel fuel oil fortified with PCP for control of bank vegetation by topkill and suppression. The oils were applied at 80, 120, and 160 gallons per acre and were applied in three series for retreatment at 4, 6, and 8 weeks after the initial treatment.

The vegetation along the ditch, which carried water intermittently about 3 or 4 days each week, was composed of smooth brome (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.), annual bromes (*Bromus* spp.), Kentucky bluegrass (*Poa pratensis* L.), Carex, sweetclover (*Meliotus* spp.), and sunflowers (*Helianthus annus* L.). Each plot extended 8¼ feet from the top of one bank, through the ditch, to the top of the opposite bank and 16½ feet along the ditch. Three replicates of each treatment were made. The chemicals were applied while water was not in the ditch.

The topkill of perennial grasses, sweetclover, and other plants caused by all rates of application of aromatic oils and by fortified diesel fuel oil was satisfactory. However, regrowth of plants after such treatment was most rapid on plots that received the lightest treatment of oil. Applications of 80 gallons per acre of two commercial weed-oil formulations and diesel fuel oil fortified with 2½ percent PCP resulted in topkills averaging about 92 percent. The two higher rates of application resulted in topkills averaging from 96 to 100 percent. There seemed little difference in the three materials as contact killers of the species present, except that the fortified diesel oil was somewhat slower in causing the plants to turn brown.

The advantages of the higher rates were less regrowth and a longer interval from treatment until regrowth began. On plots sprayed with 80 gallons per acre, regrowth of perennial grasses began 3 days after treatment and within 4 weeks was about 75 percent of the original growth. Therefore, retreatment was necessary within 4 to 6 weeks to maintain proper vegetation control. Applications at 120 gallons per acre delayed regrowth for about 14 to 18 days so that 4 weeks later there was only 20 percent regrowth. The 160-gallon-per-acre treatments delayed regrowth for 25 to 28 days, and control was satisfactory for about 2 months. Generally, the addition of each 40-gallon increment of oil, above 80 gallons per acre, resulted in 2 weeks' longer control of the vegetation in these plots.

The effect of these treatments also carried over into the 1949 growing season. Plants sprayed twice in 1948 with 120 gallons of oil or more per acre were delayed in growth and were so lacking in vigor that one well-timed application of 120 gallons of oil per acre in 1949 gave satisfactory control for the season. Plots that were sprayed two or more times in 1948 with 160 gallons of oil per acre showed reductions of stand of perennial grasses and an increase in annual weeds in 1949. Growth of perennial grasses was also suppressed in 1949.

Experiments in Utah

During 1949 and 1950 several experiments were conducted at and near Logan, Utah, to evaluate several chemicals for removing excessive vegetative topgrowth from small irrigation ditches without destroying

the bank-stabilizing root systems. The chemicals compared in these experiments were three special weed oils, furnace oil and diesel fuel both alone and fortified with DNBP, and several 1:2 oil-water emulsions. Rates of application ranged from 80 to 240 gallons per acre. One pound of DNBP per acre was used in fortifying the oils. In each test, treatments were replicated three times on plots that were 4 feet wide and 2 rods long and covered the full cross-section of the small ditches and ditchbanks.

Each treatment was repeated two or three times during the growing season. The initial treatment was made in June as soon as the topgrowth was sufficient to restrict waterflow. Subsequent treatments were made whenever weed regrowth was sufficient to hinder water passage. The dry vegetation was removed from the treated plots by burning 5 or 6 days after treatment. The weed growth removed by burning was dependent upon the effectiveness of the chemical in killing the topgrowth.

Results of the several tests conducted in 1949 and 1950 were in close agreement. All the oil sprays except the unfortified diesel oil and the oil-water emulsions gave satisfactory vegetation control when applied two or three times during the season. Application rates considered necessary for satisfactory vegetation control were 240 gallons per acre for unfortified fuel oil, 160 gallons per acre for the DNBP-fortified fuel or diesel oil, and 120 gallons per acre for the special weed oils. Results were slightly better for the higher rates of DNBP-fortified fuel oil or diesel oil and for the special weed oils but not enough better to justify the additional cost of application.

Experiments in Wyoming

Two experiments were conducted in Wyoming during 1955 to 1958 on the control of miscellaneous broad-leaved and grassy weeds growing along small, intermittently used, irrigation ditches. Both experiments were conducted at the University of Wyoming Substation, Torrington, Wyo., on a sandy loam.

The predominant broad-leaved weeds and grasses along the ditches were dandelion (*Taraxacum officinale* Weber), sweetclover (*Melilotus* spp.), smartweed (*Polygonum* spp.), rough pigweed (*Amaranthus retroflexus* L.). ditch aster (*Aster* spp.), barnyardgrass (*Echinochloa crusgalli* (L.) Beav.), green foxtail (*Seteria viridis* (L.) Beav.), bromegrass (*Bromus* spp.), and Carex (*Carex lanuginosa* Michx.).

Plots were arranged end to end along the ditch so that both ditchbanks and ditch bottom were included in each plot.

Spray applications were made with a knapsack sprayer equipped with a single-nozzle, wand-type boom, air-supply tank, and a pressure-regulator valve to maintain a constant spraying pressure. Burning was done with a hand-operated single-unit burner for 3 minutes per square rod.

Retreatments were made during the growing season as necessary to maintain adequate control of the weeds. Visual estimates of the vegetative control were made periodically during each growing season.

Abundant precipitation occurred during the spring and summer of 1957 and 1958; this probably influenced the results obtained, especially with the soil-sterilant herbicides in the experiment initiated in 1957.

Exploratory experiment (1955).—This experiment was designed to compare dalapon, amitrole, chlorazine, DNBP-fortified fuel oil, and burning with liquid propane gas for the control of miscellaneous ditch-bank vegetation. All chemicals were applied in 120 gallons of total solution per acre. The experiment was continued for 3 years.

Initial applications of dalapon and amitrole were made in June 1955. Dalapon was applied at 20 and 40 pounds and amitrole at 10 and 20 pounds per acre. Four retreatments of each were made at one-half the initial rate. All applications totaled 60 and 120 pounds per acre for dalapon and 30 and 60 for amitrole.

Chlorazine was applied at 20 pounds per acre on June 16 and August 25, 1955, and at half this rate on May 25, 1956, and July 9, 1957.

Broad-leaved weeds became a problem on the dalapon, amitrole, and chlorazine plots in 1956 and 1957. Therefore, 2 pounds per acre of the diethanolamine salt of 2,4-D were applied May 25, 1956, and July 9, 1957.

Final observations made in September 1957 showed that 90 to 99 percent of the vegetation had been controlled with these three herbicides. The lighter rates of both dalapon and amitrole were nearly as effective as the heavier rates. Chlorazine gave about the same results as the 20-pound rate of dalapon.

Seven spray applications of DNBP-fortified fuel oil containing 3 pints of DNBP in 120 gallons per acre of fuel oil maintained weed control about equivalent to chlorazine and the lighter rate of dalapon supplemented with 2,4-D over the same 3-year period. Treatments were made about the middle of June, July, and August the first year and once in the spring and again in midsummer during the second and third years.

Burning with LP gas seven times during the 3-year period on the same dates as the applications of DNBP-fortified fuel oil resulted in fair to good vegetative control. However, burning was definitely inferior to the chemical treatments, especially in 1957. Final vegetative control with burning was 70 percent.

Comparison of soil-sterilant herbicides, growth inhibitors, and burning, 1957.—In this experiment 32 treatments were compared (see tables 11, 12, 13). All treatments were replicated three times. All chemicals, except BMM, CBMM, and fenuronTCA, were applied in 120 gallons of total solution per acre. Up to 650 gallons of water per acre were required to carry fenuronTCA. The BMM and CBMM were applied broadcast as dry crystals.

All the soil-sterilant herbicides, with the exception of chlorazine at 20 pounds per acre, controlled 88 to 99 percent of the vegetation during the spring and early summer that the experiment was initiated (1957) (table 11). No retreatments were made in 1957, and by the fall of that year the plots treated with the lightest rate of erbon, fenuronTCA, CBMM, and both rates of chlorazine had considerable regrowth of vegetation. The best weed control throughout the 1957 season was obtained with the compounds least soluble in water, namely diuron and simazine (fig. 14). Monuron and BMM also maintained good weed control. Perhaps this was due to the unusually large amount of precipitation in 1957 (19.0 inches compared with the longtime average of 13.5 inches) and the location of the experiment on

FIGURE 14.—A small irrigation ditch 1 year after treatment with simazine at 20 and 40 pounds per acre to control miscellaneous weeds (foreground and middle area) and untreated (background).

rather porous sandy loam. As would be expected, little, if any, degradation of the herbicides occurred during the winter months of 1957, as shown by the degree of weed control in the fall of 1957 and the spring of 1958.

About July 1, 1958, a rank growth of annual weeds developed at and below the waterline in the ditch on most of these plots (fig. 15). This regrowth interfered seriously with the flow of water and produced a heavy crop of weed seeds.

Observations made in the fall of 1958 showed that only simazine and fenuronTCA at the higher rates tested gave satisfactory weed control throughout the 2 years of the experiment.

Dalapon, amitrole, and mixtures of each of these herbicides with 2,4-D gave fair to good weed control in 1957 (table 12). However, in the summer of 1958 broad-leaved weeds became a serious problem on all plots that were not treated with a mixture containing 2,4-D.

Final observations made in the fall of 1958 showed that the 5-pound rate of amitrole alone controlled the vegetation as effectively as dalapon alone at 20 pounds per acre (fig. 16). Dalapon and amitrole mixtures with 2,4-D were considerably more effective than either dalapon or amitrole alone. Amitrole at 5 pounds per acre plus 2,4-D at 2.5 pounds per acre repeated four times in 2 years was the only treatment with these herbicides that gave satisfactory control throughout the 2-year period.

Treatments with DNBP-fortified fuel oil at 3-, 6-, and 9-week intervals gave similar results to burning with LP gas at these same

TABLE 11.—*Comparison of soil sterilants for the control of miscellaneous ditchbank vegetation, Torrington, Wyo., 1957–58*

[Initial applications made Apr. 19, 1957; retreatments made May 17, 1958]

Chemical	Application rate per acre [1]		Control [2] of ditchbank weeds—			
			1957		1958	
	Initial	Total	June 21	Sept. 4	May 16	Sept. 25
	Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*
Monuron	10	20	98	80	85	40
Do	20	20	99	88	87	0
Do	40	40	99	95	92	0
Diuron	10	20	96	88	82	33
Do	20	20	99	97	95	0
Do	40	40	99	99	98	50
Erbon	40	80	93	45	57	38
Do	80	160	98	87	81	30
Chlorazine	20	40	30	3	6	10
Do	40	80	91	66	74	53
Simazine	20	20	99	98	97	39
Do	40	40	99	100	99	87
BMM	125	250	96	76	82	27
BMM	250	250	99	89	86	23
BMM	500	500	99	88	92	0
FenuronTCA	40	80	99	41	83	40
Do	80	160	99	76	81	83
CBMM	250	500	88	40	40	17
CBMM	500	1,000	97	81	71	27
CBMM	1,000	2,000	97	87	71	23

[1] BMM and CBMM broadcast as dry crystals, FenuronTCA applied in 650 gallons of water per acre; other chemicals, in 120 gallons.
[2] Data are averages of 3 replications of each treatment.

intervals during the first year of the experiment (table 13). However, the DNBP-fortified fuel oil appeared to have an accumulative effect, as the oil treatments were superior to burning with LP gas at the same frequencies the second year.

It appears that spraying with DNBP-fortified fuel oil every 3 to 6 weeks or burning with LP gas every 3 or 4 weeks during the growing season would give satisfactory ditchbank-weed control.

Experiments in Montana

Two types of experiments to control miscellaneous ditchbank weeds were conducted in Montana from 1953 to 1960.

Soil-sterilants.—In October 1953, four soil sterilants were compared at Bozeman and Huntley, Mont. The two ditchbanks at both locations were infested with the same plant species as follows: Kentucky bluegrass, smooth bromegrass, Canada thistle, sweetclover, goldenrod, and a few annuals. The capacity of each ditch was between 1 to 2 cubic feet per second of water. The ditch at Huntley delivered water for a 5-day period about three times per season, whereas the ditch at Bozeman was used almost continuously. The soil is of

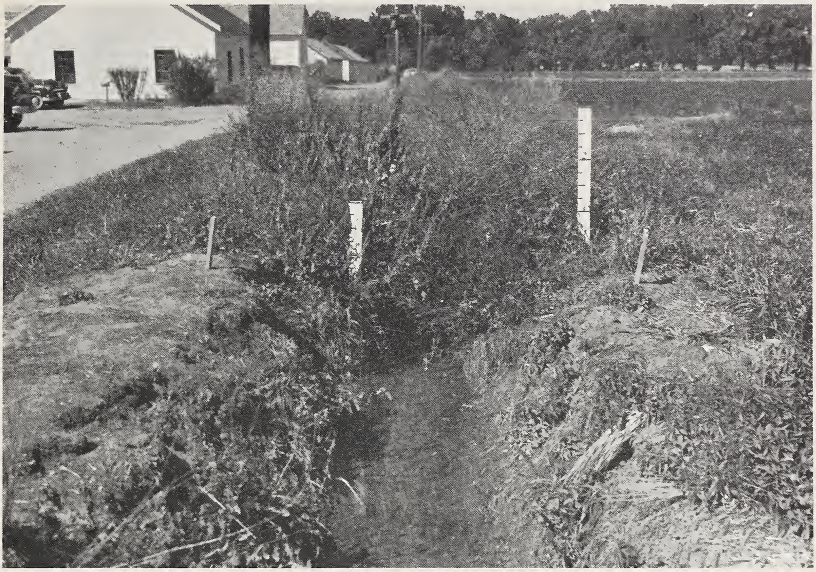

FIGURE 15.—A small irrigation ditch after a single treatment with a soil-sterilant herbicide in the spring of the first year (background) and after repeated treatment of the herbicide in the spring of each year (foreground) to control miscellaneous weeds. Photographed late in the second summer.

TABLE 12.—*Comparison of dalapon, amitrole, and mixtures of these with 2,4-D for the control of miscellaneous ditchbank vegetation, Torrington, Wyo., 1957–58*

[Initial applications made May 22, 1957; retreated once in 1957 and twice in 1958]

Chemical	Application rate per acre [1]		Control [2] of ditchbank weeds—			
			1957		1958	
	Initial	Total	June 21	Sept. 4	May 16	Sept. 25
	Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*
Dalapon	10	40	83	67	64	17
Do	20	80	86	85	66	37
Amitrole	5	20	81	95	83	33
Do	10	40	86	98	93	53
Dalapon+2,4-D	10+2	40+8	80	93	85	40
Amitrole+2,4-D	5+2.5	20+10	83	93	90	73

[1] Water at 120 gallons per acre was used as the diluent.
[2] Data are averages of 3 replications of each treatment.

TABLE 13.—*Comparison of DNBP and propane burning for the control of miscellaneous ditchbank weeds, Torrington, Wyo., 1957–58*

[Initial applications made June 5, 1957]

Chemical or type of treatment	Application rate per acre		Number of treatments [1]		Control [2] of ditchbank weeds—			
					1957		1958	
	DNBP	Fuel oil	1957	1958	June 21	Sept. 4	May 16	Sept. 25
DNBP + fuel oil:	*Quarts*	*Gallons*	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Every 3 weeks	3	120	4	4	60	95	88	100
Every 6 weeks	3	120	2	3	63	35	49	93
Every 9 weeks	3	120	1	2	73	65	23	75
Propane burner:								
Every 3 weeks	----------	----------	4	5	71	90	58	96
Every 6 weeks	----------	----------	2	3	70	46	20	67
Every 9 weeks	----------	----------	1	2	81	76	20	65

[1] All retreatments made at initial rate except last two retreatments of DNBP + fuel oil every 3 weeks. Only spot treatments were required on July 22 and August 13, 1958.
[2] Data are averages of 3 replications of each treatment.

FIGURE 16.—A small irrigation ditch after two treatments with dalapon at 10 pounds per acre to control miscellaneous weeds (foreground) and untreated (background).

heavy clay in the Huntley ditch and of Huffine silt loam in the one at Bozeman.

The treatments compared at the two locations were monuron at 20, 40, and 80 pounds, fenuron at 20 and 40 pounds, CBM at 640, 960, and 1,280 pounds, and TCA at 50 and 100 pounds per acre.

Good kill of all plants on the ditchbanks was obtained with most of the soil-sterilant treatments. Monuron at 40 and 80 pounds per acre eliminated 90 to 100 percent of all vegetation at both locations up to 20 months, or for two seasons. The 20-pound rate of monuron gave 95 percent control at Huntley for one season; but, with slightly higher rainfall and lighter soils, at Bozeman, it was not satisfactory, as it gave only 60 percent control for one season. All monuron treatments were more effective at the Huntley location.

The species least affected by monuron treatments was Canada thistle. Although monuron at 40 pounds per acre held its growth in check into the second season, it was not killed; it began recovery in the second season. Monuron at 80 pounds per acre gave very good control of all species including Canada thistle.

At Bozeman, 80 pounds of monuron per acre caused the ditchbank to erode from the action of flowing water during the second season after treatment (fig. 17). This indicates that the use of sterilants on ditchbanks subject to fast-flowing water or other factors causing erosion when soil-binding roots are destroyed is limited. Sterilants, however, are satisfactory in flat ditches that do not carry water continuously (fig. 18).

FIGURE 17.—A ditchbank after treatment with monuron at 80 pounds per acre to control miscellaneous weeds (foreground) and untreated (background). This ditch was in use for most of the irrigation season. The water flowed quite fast because of the steep slope of the ditch. Recovery of grasses is beginning along the edge of the water and the bank is eroding. Photographed 12 months after treatment.

Fenuron at 40 pounds per acre gave good ditchbank-vegetation control for one season. The 20-pound rate gave satisfactory control for one season at Huntley but very poor control at Bozeman.

CBM was effective in controlling vegetation for one season at 960 pounds or more per acre. At 1,280 pounds per acre vegetation control was quite effective in the heavy soils at Huntley even during the second season after application.

TCA gave excellent kill of grasses but poor kill of Canada thistle. Many annual weeds, such as sunflower, redroot pigweed, and lambsquarter, appeared in these plots in July after the treatments the previous October. These treatments would need followup treatments with 2,4-D to be satisfactory.

Foliage treatments (*1958*).—In June 1958, several herbicides were compared for suppression of ditchbank vegetation at Bozeman (table 14). The plant species infesting these plots were about the same as those in the soil-sterilant plots.

The ditch used for this experiment had water in it only once during the season after the treatments were made. This undoubtedly influenced the results, which appeared somewhat better than might be expected under higher moisture conditions.

FIGURE 18.—A ditchbank after treatment with monuron at 80 pounds per acre to control miscellaneous weeds (foreground) and untreated (background). This ditch had water in it only a few times each season, and it had very little slope. Photographed 2 years after treatment.

The herbicidal oil at 80 and 120 gallons per acre gave effective topkill of all vegetation (table 14). However, 40 gallons of the oil with 4 pounds of 2,4-D or dalapon ester gave topkills nearly equal to the oil alone at 80 gallons per acre. In addition, the vegetation was suppressed or controlled much better 2½ months after the treatments by the combination treatments than by the oil alone.

Results from the treatments with 2,4-D combined with herbicidal oil indicated that at least 40 gallons of oil were needed with 4 pounds of 2,4-D to give effective vegetation control. Combination of 10 or 20 pounds of 2,4-D per acre with 10, 20, or 40 gallons of oil per acre were also effective for 1 season. The high rates of 2,4-D in water gave excellent control of broad-leaved weeds but little control of grasses.

Dalapon at 10 or 15 pounds per acre applied in water was fairly effective for controlling the grasses for the season. The addition of 2,4-D with dalapon caused better control of broad-leaved species. These rates of dalapon usually caused considerable loss of grass stand, which opened the bank to invasion by other species. The application of dalapon in oil gave similar results with greater topkills and more elimination of grasses.

Amitrole at 7 and 10 pounds per acre gave good control of all vegetation during the season with 40 to 50 percent decrease in grass stand the following year. Amitrole at 4 pounds per acre was slower in bringing about vegetation control and did not kill out the grass cover.

The results indicate that all these chemicals are effective in controlling ditchbank vegetation and that certain combinations of

TABLE 14.—*Comparison of several chemicals as foliage treatments for the control of miscellaneous ditchbank weeds, Bozeman, Mont., 1958–59*

[Applications made June 18, 1958]

Chemical	Application rate per acre			Vegetation control on dates given				
	Active ingredient	Diluent		Topkill, July 7, 1958	Control on—			
					Sept. 8, 1958		June 18, 1959	
		Water	Oil[1]	All vegetation	Bdlf.[2]	Grass[3]	Bdlf.[2]	Grass[3]
	Pounds	*Gallons*	*Gallons*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
2,4-D	4	40	----------	40	100	0	90	0
2,4-D	10	40	----------	55	100	20	98	0
2,4-D	20	40	----------	65	100	40	99	0
2,4-D	40	40	----------	72	98	65	99	0
2,4-D	2	----------	10	30	90	20	20	0
2,4-D	2	----------	20	65	50	25	25	0
2,4-D	2	----------	40	85	82	48	80	0
2,4-D	4	----------	10	56	92	50	85	0
2,4-D	4	----------	20	67	95	55	80	0
2,4-D	4	----------	40	90	95	78	95	0
2,4-D	10	----------	10	63	98	85	95	0
2,4-D	10	----------	20	86	98	66	95	0
2,4-D	10	----------	40	97	99	88	95	0
2,4-D	20	----------	10	90	100	80	100	0
2,4-D	20	----------	20	97	100	87	98	0
2,4-D	20	----------	40	99	100	88	95	0

Oil only	----------	----------	80	91	50	35	30	0
Do	----------	----------	120	100	75	85	80	0
Amitrole	4	40	----------	52	100	90	95	0
Do	7	40	----------	85	98	90	100	40
Do	10	40	----------	87	100	100	95	50
Dalapon	10	40	----------	65	50	100	10	60
Do	15	40	----------	60	85	100	25	80
Dalapon+2,4-D	10+ 2	40	----------	75	95	88	50	30
Do	10+ 4	40	----------	83	100	94	60	30
Do	10+10	40	----------	95	100	91	95	40
Dalapon	4	----------	40	89	85	94	10	40
Do	10	----------	40	96	90	98	20	90

[1] Herbicidal oil containing 55 percent aromatics was used as the oil diluent.
[2] Broad-leaved species—sweetclover, goldenrod, Canada thistle, sunflower, and others.
[3] Kentucky bluegrass, orchardgrass, smooth brome, timothy, and some annual grasses.

2,4-D with amitrole or dalapon will probably give the most satisfactory control and suppression without eliminating desirable bank-stabilizing grasses.

Summary and Conclusions

In experiments in Idaho, Montana, and Utah satisfactory control of perennial grass and annual and perennial broad-leaved weeds on ditchbanks were obtained with special weed oils and with fuel oils fortified with DNBP or PCP. Two or three applications of the special weed oils at 80 to 120 gallons per acre or of the fortified fuel oils at 120 to 160 gallons per acre provided season-long control of miscellaneous ditchbank weeds. At these rates the fortified oils usually are less costly.

The addition of 4 to 10 pounds of 2,4-D to only 40 gallons of special weed oil per acre gave good seasonal control of all weeds. It also gave longer control of perennial broad-leaved weeds than 80 or 120 gallons of special weed oil and at considerably less cost.

With the present high cost and scarcity of farm labor, the oil treatments are an economical and efficient means of removing excess vegetation from small intermittently used irrigation ditches. These treatments also prevent the production of weed seeds and their dissemination to adjacent farmland by irrigation water or other means.

In Wyoming experiments, either amitrole or dalapon applied twice each year controlled miscellaneous ditchbank vegetation effectively if supplemented with light rates of 2,4-D to control broad-leaved weeds. Burning with LP gas every 3 or 4 weeks gave satisfactory control, but it was somewhat less effectual than spraying every 3 to 6 weeks with DNBP-fortified fuel oil at 120 gallons per acre.

In experiments in Wyoming and Montana, several soil-sterilant herbicides, including monuron, diuron, simazine, BMM, CBMM, and fenuronTCA, effectively eliminated ditchbank vegetation when applied in the spring. At heavy rates, simazine, diuron, and monuron gave control for 2 years under some conditions. However, ditchbank erosion may become a problem on ditchbanks of light soils and subject to fast-moving water when all vegetation is removed by soil-sterilant treatments.

WOODY PLANTS

Woody plants along streams and irrigation ditches waste large quantities of water annually. They collect debris and sediment, reduce channel capacity, and generally interfere with water delivery and ditch maintenance. Included in this group are such plants as saltcedar (*Tamarix pentandra* Poll.), willow (*Salix* spp.), cottonwood (*Populus* spp.), and wild rose (*Rosa* spp.). Saltcedar is an aggressive introduced plant that infests large areas of waterways in Arizona, southern California, New Mexico, and Texas (*11*). Robinson (*11*) reported that this plant uses 4 to 6 feet of water per season in New Mexico and Arizona. Arle and Bowser (*2*) found repeated treatments with 2,4,5-T to be effective in controlling young growth of saltcedar.

In some instances these woody species are beneficial in stabilizing

streambanks against erosion; however, their excessive water use and their interference with waterflow often make them very undesirable. These plants are also the cause of important losses in forage on rangelands throughout the West.

Willows

Various species of willows have become established along delivery and drainage channels of irrigation systems. Experiments conducted in Washington, Utah, and Wyoming proved 2,4-D to be effective for control of several species of willows. Leonard and Crafts (*10*) reported good translocation of radioactive 2,4-D in arroyo willows (*Salix lasiolepis* Benth.) from late April until late summer.

Arroyo Willow in Washington

2,4-D sprays.—Arroyo willows, about 6 feet high, dense and fully leaved, along a drainage ditch near Prosser, Wash., were treated with four rates of the butyl ester of 2,4-D in 160 gallons of water per acre on July 1, 1947 (table 15). Retreatments at the same rates were made on June 9, 1948. The plots of willows were 8¼ by 16½ feet.

TABLE 15.—*Comparison of rates of application of butyl ester of 2,4-D for control of arroyo willow, Prosser, Wash., 1947–48*

[Initial applications made July 1, 1947; retreatments made June 9, 1948]

Application rate per acre [1]		Average control (estimated) on—		
Initial	Total	Sept. 2, 1947	June 9, 1948	Aug. 17, 1948
Pounds	*Pounds*	*Percent*	*Percent*	*Percent*
0. 66	1. 32	73	81	100
1. 25	2. 50	88	91	100
2. 0	4. 0	97	98	100
2. 66	5. 32	97	96	100

[1] Water at 160 gallons per acre was used as the diluent.

All leaf growth was killed within 2 weeks after the initial 2,4-D treatments. Within 9 weeks, most of the aboveground stems and branches were dead. However, some regrowth developed on the larger treated stems from below the ground to 18 inches above ground. Also, new shoots emerged in abundance from underground plant structures at distances of 2 to 3 feet from the old growth.

Ten weeks after the 2,4-D retreatments in June 1948, willow growth was eliminated on all plots. The 2.0- and 2.66-pound rates of treatment gave somewhat better control than the lighter rates the first year. However, inasmuch as retreatments were necessary on all plots, no advantage was gained by applying more than 0.66 pound per acre per treatment.

2,4,5-T sprays.—On plots adjacent to the 2,4-D experiment arroyo willows, fully leaved and about 8 feet high, were treated with

three rates of the isopropyl ester of 2,4,5-T in 160 gallons of water per acre on June 15, 1948 (table 16). Retreatments were made at the same rates on August 17, 1948, and on October 3, 1949.

TABLE 16.—*Comparison of rates of application of the isopropyl ester of 2,4,5-T for the control of arroyo willows, Prosser, Wash., 1948–50*

[Initial applications made June 15, 1948; retreatments made Aug. 17, 1948, and Oct. 3, 1949]

Application rate per acre [1]		Average control (estimated) on—				
Initial	Total	July 1, 1948	Aug. 17, 1948	Oct. 20, 1948	Oct. 3, 1949	July 27, 1950
Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
2	6	97	30	93	90	95
3	9	98	53	95	95	99+
4	12	99	83	98	98	99

[1] Water at 160 gallons per acre was used as the diluent.

All 2,4,5-T treatments caused 97- to 99-percent kill of the willow leaf growth within 2 weeks after the first treatments. However, within 8 to 9 weeks, considerable regrowth occurred on the larger willows on all plots. The retreatments on August 17 again killed most of the new leaf growth but failed to kill all of the shoot and stem growth. Moreover, an occasional new shoot appeared on plots treated at the 2- and 3-pound rates. The third treatment, in October 1949, at the two highest rates of application was almost but not absolutely lethal to all willow growth.

Sandbar and Almond-Leaved Willow in Utah

Several types of willow are commonly found growing along irrigation systems in Utah and include sandbar willow (*Salix exiqua* Nutt.), almond-leaved willow (*Salix bebbiana* Sarg.), and black willow (*Salix* spp.).

Two experiments were conducted near Paradise, Utah, during 1948 to 1952, for control of sandbar and almond-leaved willow growing along an irrigation canal. Wild rose (*Rosa woodsii* Lindl.) was also present on most of the plots.

Experiment begun in August 1948.—An exploratory experiment was conducted to compare the alkanolamine and butyl ester of 2,4-D and the isopropyl ester of 2,4,5-T. The three chemicals were compared at rates of 2 and 4 pounds per acre, each applied in 160 and 480 gallons of water per acre.

Observations made June 28 and August 10, 1949, showed that all three chemicals gave fair to good kills of the topgrowth of both species of willows. The almond-leaved willow was definitely more resistant to the chemicals than the sandbar willow.

Regrowth was quite erratic and showed no definite differences between the effectiveness of the various chemicals. In general, the amine salt of 2,4-D tended to be least effective. Regrowth of willows

averaged somewhat less on plots receiving the heaviest rate and on plots sprayed with the greatest volume.

In addition, it was observed that the ester of 2,4,5-T also gave good topkills on wild rose while the 2,4-D sprays had little effect on it.

Experiment begun in September 1948.—In the second experiment, started in September 1948, three herbicides were tested at three different concentrations and at three dates of application (table 17). The initial applications were made in September 1948, June 1949, and August 1949. Retreatments were made in 1949, 1950, and 1951. Two additional herbicides were applied at the last initial date of application, August 1949. Water was used as the diluent in all treatments and the spray was applied with a high-pressure sprayer and orchard gun. Sufficient spray was used to give a thorough and uniform wetting of the foilage. The volume of spray varied with the density and height of the woody growth and ranged from 2 to 4.4 gallons per square rod. All treatments were replicated twice on plots 3 square rods in size.

Ester and amine formulations of 2,4-D (table 17) were both effective for control of sandbar and almond-leaved willows, but less of the ester was required for equivalent control. At equivalent rates, both formulations of 2,4-D were usually more effective on these willow species than was the isopropyl ester of 2,4,5-T.

Control of willows was not consistently any better with the higher rates of 2,4-D and 2,4,5-T than with the lower rates tested. Almond-leaved willow was again definitely more difficult to kill with either 2,4-D or 2,4,5-T than was sandbar willow.

While some of the initial treatments showed as much as 75 percent topkill of the willow, considerable regrowth occurred in most instances. By following the initial application of 2,4-D and 2,4,5-T with retreatments in 1949, 1950, and 1951, the stand of willow was further reduced.

Black Willow in Utah

Many of the black willow trees (*Salix nigra* Marsh.) growing along irrigation canals in Utah are large trees, 50 to 60 feet tall, and usually have one to eight or more trunks growing in a tight clump. Where such large trees are removed by cutting they usually sprout profusely and create problems that may be as serious as the original tree. If pulled out, damage to the canal bank may be severe and result in leaks that are difficult to repair. Because of their great height and their spreading habit of growth, control by foliar herbicide treatments is not feasible in many situations.

An experiment was begun in September 1948 in which AMS and the isopropyl esters of 2,4-D and 2,4,5-T were compared as cambium treatments for the control of black willow trees. Fifteen trees from 50 to 60 feet tall with trunks ranging from 3 to 8 inches in diameter were first treated in September 1948. Individual trees had 1 to 18 branches, or trunks. All trunks on a particular tree received the same treatment and were considered as a single tree. The herbicides were applied undiluted in cups chopped into the base or in holes bored into the base of the trunks at 6-inch intervals (table 18).

All living trunks were re-treated July 18 to 20, 1949, August 22 to 23, 1950, and August 23, 1951, in holes bored into the base of the

TABLE 17.—*Effect of time of application and rate and kind of herbicide on the regrowth of sandbar and almond-leaved willow, near Paradise, Utah, 1948–52*

Dates of applications and chemicals	Concentration of chemical	Total 2,4-D or 2,4,5-T applied per acre, 1948–52 [1]	Regrowth [2] of willows on—			
			Sept. 13, 1949	July 18, 1950	Aug. 7, 1951	July 8, 1952
Initial treatments, Sept. 16 or 20, 1948; retreatments, Sept. 13 or 14, 1949, Aug. 1 or 2, 1950, and Sept. 21 or 22, 1951:	*P.p.m.*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*
2,4-D, amine salt	750	7. 7	40	2	3	0
Do	1, 125	11. 3	38	3	3	0
Do	1, 500	17. 0	40	5	1	0
2,4-D, isopropyl ester	375	4. 3	55	19	3	(3)
Do	750	8. 6	28	12	3	(3)
Do	1, 125	12. 1	32	6	4	0
2,4,5-T, isopropyl ester	375	4. 6	58	28	6	6
Do	750	8. 1	63	19	9	0
Do	1, 125	13. 3	75	25	13	0
Initial treatments, June 27 or 28, 1949; retreatments, Sept. 6, 1950, and Sept. 21 or 22, 1951:						
2,4-D, amine salt	750	6. 9	------	50	2	0
Do	1, 125	8. 9	------	65	1	0
Do	1, 500	11. 1	------	45	9	8
2,4-D, isopropyl ester	375	3. 3	------	55	6	2
Do	750	6. 8	------	25	1	(3)
Do	1, 125	8. 8	------	50	4	0
2,4,5-T, isopropyl ester	375	3. 8	------	80	24	3
Do	750	6. 3	------	55	34	(3)
Do	1, 125	9. 9	------	93	25	0
Initial treatments, Aug. 16 to 18, 1949; retreatments, Aug. 15 or 16, 1950, and Aug. 15, 1951:						
2,4-D, amine salt	750	7. 5	------	50	4	10
Do	1, 125	12. 1	------	49	23	0
Do	1, 500	16. 1	------	49	9	(3)
2,4-D, isopropyl ester	375	4. 4	------	50	7	0
Do	750	9. 9	------	47	17	10
Do	1, 125	12. 3	------	47	5	0
2,4,5-T, isopropyl ester	375	4. 2	------	50	17	0
Do	750	7. 2	------	50	3	0
Do	1, 125	10. 4	------	50	5	0
2,4,5-T, butoxy ethanol ester	--------	7. 7	------	50	7	0
2,4-D acid + diesel oil, 3 percent	--------	7. 4	------	50	4	15
Do	--------	11. 5	------	50	18	12

[1] Water was used as the diluent; it ranged from 2 to 4.4 gallons per square rod.
[2] Data are averages of 2 replications of each treatment.
[3] Trace.

TABLE 18.—*Comparison of three chemicals used in basal applications for control of black willow trees, near Paradise, Utah, 1948*

[Initial applications made Sept. 7, 1948; all retreatments made in holes bored into base of tree trunks]

Method of applying initial application and chemical	Initial application rate of chemical—		Willow tree trunks	Holes or cups per tree	Regrowth of willow trees on—			
	Per cup or hole[1]	Per tree			July 13, 1949	Aug. 11, 1950	Aug. 8, 1951	July 14, 1952
	Table-spoons	*Table-spoons*	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
In holes chopped into the base of tree trunks:								
AMS	1	15	10	15	100	52	12	2
AMS	2	28	7	14	100	15	2	0
2,4-D, isopropyl ester	½	12	11	24	52	12	1	4
Do	1	8	4	8	15	5	0	1
2,4,5-T, isopropyl ester	1	8	2	8	70	48	12	13
Do	2	36	10	18	55	23	3	5
In holes bored into the base of the tree trunk:								
AMS	2	28	2	14	50	0	0	0
2,4-D, isopropyl ester	⅓	6	3	17	15	0	0	3
2,4,5-T, isopropyl ester	⅔	10	1	16	85	15	0	0

[1] Retreatment rate in 1949 and 1950 was the same as the initial rate; in 1951 it was doubled.

trunk. The rate of application for the retreatments in 1949 and 1950 were the same as the initial treatments except that the treatments were doubled for all trunks with 50 percent or more live growth. All rates were doubled in the 1951 retreatments.

Observations made in 1949, showed that 2,4-D was much more effective in controlling black willow trees than 2,4,5-T or AMS (table 18). In 1950, 2,4-D was still the most effective treatment; however, results with AMS were much improved where retreatments were made in holes bored in the trunks instead of in chopped cups. In 1951 and 1952, kill from AMS improved even more and AMS was as effective as 2,4-D. In 1951 and 1952, 2,4,5-T also showed improved kills.

None of the trees were killed by the initial applications. Four trees were killed after the 1949 retreatments, and three more were killed after the 1950 retreatments. By 1951 the trees not killed by earlier applications were severely injured and in many instances had only one or two small branches still showing life. The leaves on these surviving branches were small and yellow and showed severe injury symptoms. In nearly all cases, the heavier rate gave better results than the lighter rate of chemical.

In 1952, after 4 treatments in 4 years, 7 of the 15 original treated black willow trees were dead. Six trees showed only a trace to 5 percent of the original wood still living, another one had 10 percent still alive, and another had 25 percent still alive.

Summary

Three species of willow, *Salix lasiolepis*, *Salix exigua*, and *Salix bebbiana*, were eradicated by repeated 2,4-D or 2,4,5-T treatments to actively growing foliage. The 2,4-D treatment was more effective than the 2,4,5-T and the ester formulation of 2,4-D was better than the amine.

Large black willow trees were killed by applications of 2,4-D or 2,4,5-T ester or AMS applied in holes drilled in the base of the trunks. Eradication of black willow trees required repeated treatments with these chemicals every year for several years.

Wild Rose

Wild rose (*Rosa* spp.) is a common pest along irrigation canals, fence rows, and field margins in many irrigated areas of the West. This plant causes important losses by interfering with the proper maintenance of canals, obstructing waterflow in small irrigation ditches, and by transpiring large quantities of irrigation water.

With the advent of 2,4-D many irrigation systems were treated with this herbicide for control of willow, Canada thistle, and other broad-leaved weeds. Generally, 2,4-D had little effect on wild rose. When willows and other competing vegetation were removed, wild rose became very aggressive and in many instances was more difficult to control than was the original vegetation (fig. 2).

Experiments in Utah

Seven experiments were conducted near Logan, Utah, during 1949 to 1954, on control of wild rose (*Rosa woodsii* Lindl.) growing along

irrigation systems and fence rows. Each of these experiments was continued for several years, and final observations were made the year after the last herbicide application.

The plot size and the nature of the infestation varied among the experiments. All plots were the full width of the infested area. Applications were made with a single-nozzle, wand-type boom from both sides of the infested area to insure uniform application and complete coverage and wetting of the foliage.

In four of the experiments several herbicides were compared as foliage treatments. Effects of stage of plant development at the time of application were also compared in the foliage tests. The other three experiments were for comparing herbicides applied during the winter months when the plants were dormant. Both overall and basal applications were applied to the dormant wild rose plants.

In making the herbicide treatments in the experiments started in 1949 and 1951, several concentrations of each chemical were applied in a diluent; sufficient spray was used to thoroughly wet all the foliage. The height, density, and area of infestation varied from plot to plot; therefore, the volume of spray as well as the rate of herbicide applied varied widely from plot to plot, which made valid comparison of treatments difficult.

The procedure was changed in experiments started in 1952 and 1953 so that a known volume and rate of application was made to each plot according to the plot size.

2,4-D, 2,4,5-T, and mixtures of the two as foliage sprays.—An experiment was started June 23, 1949, for comparing the isopropyl ester of 2,4,5-T, a 1:1 mixture of the isopropyl esters of 2,4,5-T and 2,4-D, and a 1:2 mixture of the butoxyethanol esters of 2,4,5-T and 2,4-D. Applications were made on two dates—June 23 at the late-bloom stage and August 9 at the late-fruiting stage. All three chemicals were applied at concentrations of 1,000, 1,500, and 2,000 p.p.m. in water. Enough spray was applied to give thorough coverage of the foliage. Each treatment was replicated twice.

Retreatments were made with the same chemical and at the same concentration as for the initial treatment on August 12, 1950, August 17, 1951, July 9, 1952, and July 11, 1953. The wild rose never bloomed after the initial treatments in 1949, so the retreatments could not be made at different stages of growth each year.

Observations made June 14, 1953, showed that the average survival of wild rose ranged from 5 to 80 percent where the first treatments were made at the full-bloom stage with annual treatments for 3 years thereafter. The average survival was 50 to 75 percent where the first treatments were made at the fruiting stage with three annual treatments afterward. Most of the regrowth on plots initially sprayed at the bloom stage was from roots, but most of that on the plots initially treated in the fruiting stage was from topwood and ranged up to 31 percent. These results indicate a definite advantage for spraying wild rose early in the summer and not later than the full-bloom stage. It also shows that where repeated spray applications are made only once each year progress toward final elimination of the stand is slow.

Date and concentration of 2,4,5-T foliage sprays.—An experiment was begun in 1951 to further substantiate the effectiveness of

2,4,5-T applied before full bloom for control of wild rose, as determined in the 1949 experiment. Treatment data are given in table 19.

Initial observations of results made on September 17, 1951, showed that all treatments gave good foliage kill. However, heavy regrowth had developed from the roots and surviving topwood by June 19, 1952, so that the initial application showed little reduction in wild rose at this time. Observations made in July 1954 showed that applications made at the full-leaf stage were more effective in controlling wild rose than those at later stages of growth. In general, the lower rate was just as effective as the higher rate.

Results of this test indicate that at least three or four, and usually more, applications of an ester of 2,4,5-T, applied twice a year, are necessary to give a high percentage reduction in the stand of wild rose (fig. 19).

TABLE 19.—*Effect of stage of growth and concentration of 2,4,5-T foliage sprays for control of wild rose, started near Logan, Utah, 1951–54*

Growth stage and concentration of 2,4,5-T	Application rate per acre		Regrowth [1] of wild rose on—		
	Initial	Total	June 19, 1952	June 10, 1953	July 21, 1954
Initial treatment, May 10, 1951; retreatments, Aug. 21, 1951, June 19 and Sept. 12, 1952, and July 9, 1953:	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*
Full-leaf—1,000 p.p.m.	2.1	7.5	30	1	(2)
Full-leaf—2,000 p.p.m.	3.8	15.5	73	2	0
Initial applications, June 4, 1951; retreatments, Sept. 20, 1951, July 25 and Sept. 12, 1952, and July 22, 1953:					
Bud-to-first-bloom—1,000 p.p.m.	1.5	7.0	75	20	11
Bud-to-first-bloom—2,000 p.p.m.	2.9	8.8	20	5	5
Initial applications, June 22, 1951; retreatments, Sept. 20, 1951, July 25 and Sept. 12, 1952, and July 22, 1953:					
Full-bloom—1,000 p.p.m.	2.3	8.5	33	6	1
Full-bloom—2,000 p.p.m.	4.8	19.3	40	7	8

[1] Data are averages of 2 replications of each treatment.
[2] Trace.

Formulation and rate of foliage sprays.—An experiment was initiated July 1, 1952, to compare the effectiveness of five formulations of 2,4,5-T and brush-killer mixtures of 2,4-D and 2,4,5-T. The formulations tested were the propylene glycol butyl ether, the butyl ether, and the tetrahydrofurfural esters of 2,4,5-T; 1:1 mixtures of the propylene glycol butyl and tetrahydrofurfural esters of 2,4-D and 2,4,5-T; and a 2:1 mixture of the butoxy ethanol esters of 2,4-D and 2,4,5-T. Each of the formulations was applied at rates of 1.5 and 3.0 pounds per acre in 160 gallons water per acre. Each

FIGURE 19.—Wild rose along a ditch in Utah sprayed twice with 2,4,5-T at 2 pounds per acre (left) and untreated (right).

treatment was replicated twice along separate small irrigation canals.

Each plot was retreated July 7, 1953, with the same chemical, and at the same rate of application, as was used for the initial application. Very little regrowth occurred during the rest of the season after the initial application in 1952 or after the retreatment made in 1953. For this reason the plots were not re-treated in the fall of either year.

Foliage kill of wild rose on September 8, 1952, was nearly complete for all treatments. Observations made June 5, 1953, showed considerable regrowth on all plots. Most of the regrowth came from the roots. On this date, formulations containing only 2,4,5-T appeared to give better results than those containing a mixture of 2,4-D and 2,4,5-T. Also there was a tendency for the 3-pound-per-acre rate of application to give better results than the 1.5-pound-per-acre rate. The total regrowth June 5, 1953, ranged from 23 to 60 percent for the various treatments.

Regrowth May 5, 1954, ranged from 0 to 15 percent. The propylene glycol butyl ether and the butoxy ethanol esters of 2,4,5-T gave somewhat better results than the other esters of 2,4,5-T or mixtures of 2,4,5-T and 2,4-D that were included in this test. In most instances the 3-pound rate gave slightly better results than the 1.5-pound rate. However, results were probably not enough better for the higher rates to justify the added expense of the treatment.

All plots were burned in the spring of 1954 to remove the dense mat of dead woody growth, which interfered with chemical retreatments and observations of results. One replication of treatments was located on a ditchbank grazed by cattle and the other on a ditchbank grazed by sheep. Many of the plots showed regrowth

after the dead growth was burned but cattle and sheep ate the tender new rose shoots before they made sufficient growth to re-treat.

Observations made in 1955 showed that wild rose was still alive on many of the plots but that cattle and sheep were still eating the new growth as fast as it appeared. Thus, when rose is located on ditchbanks in pastures, cattle or sheep may keep it under control if the woody topgrowth is first killed by spraying and removed by burning to allow the animals to get at the tender new shoots as they appear.

Stage of growth and concentrations of 2,4,5-T.—In this experiment, the propylene glycol butyl ether ester of 2,4,5-T was applied at six stages of growth of wild rose (table 20). The 2,4,5-T was applied at 2 and 8 pounds per acre for the dormant-spray applications and 2 pounds per acre for the treatments made at the active stages of growth. Each treatment was replicated three times.

All plots that were treated at the preleaf, full-leaf, bud, or full-bloom stages of growth were re-treated once during the summer or early fall of 1953 with the same chemical and at the same concentration as for the original treatment. Surviving foliage or new regrowth that received followup treatments was considerably less than when the initial treatments were made; consequently, less chemical was used. After the first year most of the topgrowth had been killed and it was not possible to re-treat at the same stage of growth as the initial treatments were made. For this reason all plots were re-treated with a spray solution containing 2,4,5-T at a concentration of 1,500 p.p.m. on June 8 and September 14, 1954. A sufficient volume of spray was used to give thorough coverage of all regrowth, which resulted in a slight variation in amount of 2,4,5-T applied to each plot.

Regrowth in September 1954, prior to the second retreatment that year, ranged from 17 to 63 percent (table 20). Treatments made initially at the full-leaf stage of growth gave the best control of wild rose, and those made at the bud and full-bloom stages of growth gave next best control.

Observations made in July 1955 showed that control of wild rose had improved on nearly all plots after the retreatments made in September 1954. Plots treated initially at the full-leaf stage still showed the least regrowth. However, treatments made initially at the bud and full-bloom stages of growth were only slightly less effective. Thus, as treatments were repeated, the initial advantage of treatments made at the full-leaf stage over those made at bud and full-bloom stage decreased. Treatments made at other stages of growth were still somewhat less effective.

As in previous experiments, the wild rose stand had been greatly reduced by four applications of 2,4,5-T over a 2-year period. Thus, it appears that eradication can be achieved by continuing the retreatments on actively growing foliage twice each year (fig. 20).

Dormant-spray experiments (1949–51).—In two tests, started in 1949 and 1951, various sprays were applied overall and basally to the dormant rose bush.

The herbicides compared in the 1949 test were the isopropyl ester of 2,4,5-T, a 1:1 mixture of the isopropyl esters of 2,4,5-T and 2,4-D, and a 1:2 mixture of the butoxy ethanol esters of 2,4,5-T and 2,4-D. Each treatment was made on November 25, 1949, and on March 28,

TABLE 20.—*The effect of stage of growth and rate of application of 2,4,5-T on control of wild rose, Nibley, Utah*

[The propylene glycol butyl ether ester form of 2,4,5-T was used]

Growth stage	Date of initial application (1953)	Application rate per acre: Diluent: Water	Diluent: Oil[1]	Chemical: Initial	Chemical: Retreatments: 1953	Retreatments: June 8, 1954	Retreatments: Sept. 14, 1954	Chemical: Total	Regrowth[2] of wild rose on— Sept. 14, 1954	Regrowth of wild rose on— July 3, 1955
		Gallons	*Gallons*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*
Preleaf	Mar. 6	70	10	2.0	3.3	2.3	2.3	9.9	33	14
Do	do	70	10	8.0	3.3	2.1	2.1	15.5	28	22
Full-leaf	May 25	160	---	2.0	1.7	1.5	1.6	6.8	17	2
Bud	June 22	160	---	2.0	1.8	2.4	2.5	7.7	25	4
Full-bloom	July 8	160	---	2.0	1.0	1.7	1.7	6.4	25	4
Post-bloom	---	160	---	2.0	0	2.2	2.2	6.4	34	39
Leaves dropped	Nov. 30	70	10	2.0	0	2.4	2.3	6.7	28	7
Do	do	70	10	8.0	0	1.8	1.8	11.6	63	32

[1] Diesel oil with 2 percent emulsifier.
[2] Data are averages of 3 replications of each treatment.

FIGURE 20.—Wild rose along a ditch in Utah sprayed three times with 2,4,5-T at 2 pounds per acre.

1950. Each chemical was compared at concentrations of 0.4 and 0.8 percent in diesel oil applied as an overall spray and at concentrations of 1.6 and 3.2 percent applied to the lower 18 inches of the plant. Each treatment was replicated three times.

The herbicides compared in the 1951 test were the propylene glycol butyl ether (PGBE) ester of 2,4,5-T, a 1:1 mixture of the PGBE esters of 2,4,5-T and 2,4-D, and a 1:2 mixture of the butoxy ethanol esters of 2,4,5-T and 2,4-D. Each of these herbicides was applied as an overall spray in April 1951 at concentrations of 0.4 and 0.8 percent in 70 gallons of water and 10 gallons of diesel oil. Three replicates of each were made.

Results of both the 1949 and 1951 tests were very disappointing. Observations made in July 1950 on the test started in 1949 showed 100 percent regrowth of wild rose either from woody topgrowth or from roots. Topkills of the overall spray applications made in November 1949 averaged 13 to 57 percent for duplicate plots; whereas, the March 1950 application averaged 37 to 67 percent. The basal applications gave very little topkill at either date.

Topkills of wild rose in the test started in 1951 ranged from 47 to 93 percent; but regrowth was heavy on all plots in 1952, so that the total stand of wild rose surviving approached 100 percent. Results from these dormant-spray treatments were not nearly so good as from foliage-spray treatments made at the full-leaf and early-bloom stages of growth in other experiments.

Dormant-spray experiment (***1953***).—The third experiment for testing dormant-spray applications for control of wild rose was initi-

ated November 11, 1953. The herbicides compared in this test were the PGBE ester of 2,4,5-T and a 1:1 mixture of the PGBE esters of 2,4-D and 2,4,5-T. Both chemicals were applied at concentrations of 2 and 8 percent in diesel oil. Treatments were applied to the lower 15 inches of the plant, with sufficient material being used to completely wet this part of the plant.

Results in this test, like those of earlier tests with dormant treatments, were unsatisfactory. The survival of wild rose on plots treated with a total of 31 pounds per acre of 2,4,5-T averaged 58 percent, and on plots treated with the same amount of the 2,4-D and 2,4,5-T mixture it was 85 percent. Even rates of application equivalent to 117 pounds per acre failed to give complete elimination of wild rose. Survival averaged 8 percent on plots treated with 2,4,5-T and 28 percent on plots treated with the mixture. Although this latter test did indicate that dormant applications of herbicide would give a high percentage reduction in the stand of wild rose under some conditions, the cost of application would be much greater than for treatments to the green foliage.

Summary

The ester form of 2,4,5-T was more effective than 2,4-D or mixtures of 2,4-D and 2,4,5-T in controlling wild rose. Foliage applications of all three materials were more effective in controlling wild rose than dormant applications. The cost of foliage applications is much less

Applications of 2,4,5-T initiated in the full-leaf to early-bloom stages of development gave the best control of wild rose. Also two treatments per season, at the full-leaf to early-bloom stages and again before fall frosts, gave much greater control of wild rose than only one treatment per year. Wild rose was nearly eliminated by spraying with 2,4,5-T twice each year for 2 or more years.

SUMMARY

Cooperative investigations were conducted by the Crops Protection Research Branch of the Agricultural Research Service of the United States Department of Agriculture and the State agricultural experiment station at Meridian, Idaho (1948–49), Logan, Utah (1948–54), Prosser, Wash. (1947–60), Bozeman and Huntley, Mont. (1953–60), and Laramie, Wyo. (1955–59). The effectiveness of various herbicides on 10 typical species or mixtures of the 4 major types of ditchbank weeds was determined in a total of 38 field experiments. Treatments were designed to eliminate undesirable species and vegetation in some situations and to control or suppress growth of desirable soil-stabilizing vegetation in other situations. Usually, an experiment with a given species was repeated two or more times in different years and each experiment was continued 2 or more years for retreatments and observation of results.

Close liaison was maintained between investigators at the various stations, and there was considerable similarity in method of approach and general procedure. However, details of procedure varied with species of weeds, types of ditchbanks, and local situations as necessary

to provide the most suitable experimental conditions in each situation. Experimental plots were laid out along ditches of different capacities and season of use where the particular weed species occurred naturally.

Control of reed canarygrass for more than 8 weeks was obtained in Montana with single applications of amitrole at 10 pounds per acre or dalapon at 20 pounds per acre or with three applications of an aromatic oil at 100 or 120 gallons per acre. Amitrole with ammonium thiocyanate (amitrole-T) was much more effective than amitrole alone. Monuron and simazine at heavy rates gave complete eradication of canarygrass and sterilization of the ditchbank for 2 years.

In Utah, monuron, sodium chlorate, and CBM at heavy rates failed to give satisfactory control of canarygrass especially in a 2- to 3-foot wide strip above the waterline in canals with continuous flow of water. After the vegetation high on the banks had been killed, which left a fringe of surviving canarygrass at the waterline, the banks tended to crack and slough into the canal.

Monuron at 20 to 40 pounds per acre or more controlled quackgrass 2 years or longer in Utah and Washington. The more soluble sodium chlorate, TCA, and CBM gave good control on the ditchbank in Utah. However, it quickly leached out of the ditch bottom and failed to control quackgrass longer than a few months in small intermittently used irrigation ditches.

Eradication of Carex from irrigation ditches was accomplished in 2 years or less in Wyoming by repeated applications of 2,4-D at 40 to 80 pounds or of amitrole at 5 to 10 pounds per acre. Repeated applications of DNBP-fortified fuel oil at intervals of 3 to 6 weeks eliminated Carex in 2 years. Repeated burning with LP gas at 3-week intervals or repeated spraying with dalapon at 20 pounds per acre gave only seasonal control. Several soil-sterilant herbicides gave unsatisfactory results especially at the waterline. The heavy rates of 2,4-D encouraged development of a desirable dense stand of Kentucky bluegrass, which effectively prevented invasion by Carex or other weeds for at least 3 years after termination of the chemical treatments.

Initial applications of sodium chlorate at 4 or more pounds or CBM at 6 or more pounds per square rod plus spot treatments in 3 subsequent years gave complete eradication of Canada thistle on the top and shoulder of a canal bank in Washington. These treatments did not eliminate the thistle from a 2- to 3-foot margin immediately above the waterline. However, the soil was denuded above the waterline for sufficient lengths of time to cause severe scouring, or erosion, of the bank. In another Washington experiment 2,3,6-TBA at 10 to 40 pounds and PBA at 20 to 80 pounds per acre reduced the stand of Canada thistle 87 to 100 percent and permitted sufficient survival of grasses to stabilize the ditchbanks against erosion or scouring.

Generally satisfactory control of Canada thistle on canal banks in Washington resulted from repeated applications of 2,4-D or MCPA at 2 pounds per acre or more. Three spray applications each growing season were necessary for the most effective control. The amine salts and esters of 2,4-D were equally effective, and 2,4-D was as effective as the more expensive MCPA or 2,4,5-T. A dense stand of redtop, bluegrass, and other grasses that developed during the treatments

provided strong competition with surviving Canada thistle shoots and seedlings and with other weeds.

Waterhemlock was eradicated on an irrigation ditchbank in Washington by one or two applications of either 2,4-D or 2,4,5-T at 1 or 2 pounds per acre. Initial late-spring or early-summer applications appeared slightly more effective than those initiated in late summer. Amitrole, erbon, 2,3,6-TBA, and esters of dalapon and silvex were less effective on waterhemlock than 2,4-D or 2,4,5-T.

Satisfactory control of mixtures of annual and perennial weeds along small intermittently used irrigation ditches was obtained in Idaho, Utah, and Wyoming with repeated applications of aromatic oils or DNBP- or PCP-fortified fuel oils at 120 to 160 gallons per acre. Retreatments were necessary every 6 to 8 weeks with the aromatic oils and every 3 to 6 weeks with the fortified fuel oils. Aromatic weed oil at 40 gallons per acre plus 4 pounds of 2,4-D was as effective as 120 gallons per acre of oil alone in Montana and was less expensive.

Repeated burning with LP gas at intervals of 3 to 6 weeks gave fair to good seasonal control of ditchbank weeds in Wyoming, but this was less effective than spraying with DNBP-fortified fuel oil at the same intervals.

Amitrole at 5 to 10 pounds or dalapon at 10 to 20 pounds per acre gave good control of miscellaneous ditchbank weeds in Wyoming. After these treatments had eliminated the grasses, it was necessary to apply a light rate of 2,4-D to control broad-leaved weeds.

Monuron at 20 to 80 pounds per acre gave good control of ditchbank vegetation for 1 to 2 years in Montana and Wyoming. In Wyoming, other soil-sterilant herbicides, including diuron, simazine, fenuronTCA, CBMM, and BMM, also controlled vegetation on ditchbanks for 1 to 2 years. Erosion of ditchbanks was a serious problem along ditches with light soils or fast flowing water after the banks had been denuded by soil-sterilant herbicides. Diuron, monuron, and simazine did not satisfactorily control deep-rooted perennial broad-leaved species, such as Canada thistle, milkweed, dock, and wild licorice.

Willows were readily eradicated by repeated applications of 2,4-D or 2,4,5-T at relatively low rates in Utah and Washington. Applications of 2,4-D were slightly more effective on willows than applications of 2,4,5-T but much less effective than 2,4,5-T on wild rose, which occurred interspersed among the willows in the Utah experiments. Less isopropyl ester of 2,4-D than of alkanolamine salt was required to eliminate willows in Utah.

Large black willows were killed in Utah by repeated applications of high concentrations of 2,4-D or 2,4,5-T ester or with crystals of AMS in cups or holes made in the tree trunks at 6-inch intervals around the base. The 2,4-D treatments gave a more rapid kill.

Wild rose was eradicated in Utah by repeated foliage applications of esters of 2,4,5-T at concentrations of 1,000 to 2,000 p.p.m. in water. Mixtures of 2,4-D and 2,4,5-T were less effective than 2,4,5-T alone. Applications at the full-leaf to the full-bloom stages of wild rose were much more effective than those at later stages of growth. Dormant-season spray applications of 2,4,5-T at high concentrations in diesel oil gave some kill of topgrowth but little reduction in the stand of wild rose.

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